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The RMA ENGINEER

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ENGINEERING DIVISION

OF THE

Radio Manufacturers Association

Volume 1 March, 1937 Number

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Limitations in Radio Receiver Design Due to Variations in Tubes

By C. R. Barhydt, General Electric Company

n the design of a radio receiver the engineer must ept compromises between various operating charac- stics. He cannot design for extreme sensitivity hout being faced with an undesirable noise condition.) great selectivity, while improving station separation, its the range of audio response; an a-v-c system design- to bring in weak and strong signals at equal volume els aggravates the effects of selective fading. It is iatter of good judgment based largely on experience, choose characteristics which provide satisfactory over- performance, at the same time minimizing all un- irable responses.

n addition to the engineering compromises with ch he is faced the engineer must be cost conscious. we spend more and more money on dials, automatic ing mechanisms, etc., the engineer must provide sfactory operating characteristics at lower and lower :. The components must either cost less or he must them in smaller number. He has widened tolerances far as he can without producing widely different formance characteristics between receivers built on same production line. He has, however, to a large ent, maintained complete control over the specifica- is for component parts so that he is in a position to w what these variations in performance will be. one component over which he exercises little control he matter of tolerances is the vacuum tube. Tube ipanies have shown a reluctance in the past to publish rances or limits to which the engineer may design. knows what to expect of capacitors, resistors and s for which he provides specific tolerances himself, he has very little control over the tubes he uses. may, for instance, design an audio system which is from hum in the laboratory because the tubes he used had little or no heater-cathode leakage, and r be faced with a production shut-down due to ier leakage tubes that are considered a satisfactory duct.

t is the purpose of this paper to review some of the cts of variations in tube characteristics on receiver formance and to indicate means of minimizing the nces of production and field troubles resulting there- n. In the development of a receiver line consisting wenty or more different chassis in a limited time by nall group of engineers, tube performance is too often en for granted. The best the engineer can do is ry a number of tubes in his set and note variations performance. While this may sometimes indicate gn weaknesses, it often fails to do so.

he discussion which follows is only partially quantita- because of the lack of specific tube data which npts this discussion. Tests were made to show the ct of commercial variations in g_m on conventional iver performance, and the results are given below. er comments are based largely on observation and oretical considerations.

Variation in Performance Due to g_m

The following tests were made to determine just what happens when a set is provided with tubes having g_m at the higher and lower limits. These limits were obtained by actual measurement of a large number of tubes, the highest and lowest being chosen as limits. The procedure was to supply the receiver with all low limit tubes for the first test and all high limit tubes for the second. Two receivers were used—a 6-tube and a 10-tube having tube complements indicated in Table No. 1:

Table No. 1

			g_m	
	6-Tube	**10-Tube**	**Hi**	**Lo**
R-F Amp.	....	6K7	1800	1350
Converter	6A8	6A8	700 2100	325(1) 1150(2)
1st I-F Amp.	6K7	6K7	1800	1350
2nd I-F Amp.	....	6K7	1800	1350
Diode Detector	6H6	6H6	....	....
Audio Amp.	6F5	6F5	1800	1350
Power Output	6F6	6L6	3000 6400	2500 5400
Tuning Meter (D-C Amp.)	....	6C5	2450	1900
AFC Control	....	6J7	1500	1175
Rectifier	5W4	5Z4	....	....

(1) Conversion conductance.

(2) Oscillator transconductance.

The results of the tests are given in Table No. 2:

Table No. 2

	6-Tube		10-Tube	
	Hi g_m	**Lo g_m**	**Hi g_m**	**Lo g_m**
Sensitivity (Micro V.)	11.6	20.3	0.52	1.20
Power Output—Max.	4.6	4.2	12.2	13.7
Power Output—Undis.	1.95	1.92	7.3	6.8
Osc. Starting (Line volts)	65	98	61	65
Conversion gain	58	47	......	......
AVC-DB (IRE test)	57.1	52.4	52.8	46.6
Tuning Meter Sens.	......	......	5.8	15.4
AFC Control	......	......	405	570
% Dist. at 2V. R-F Input	5	11	2.8	4.0

The tuning meter tube was connected as a d-c amplifier and varied 2.6 to 1 in sensitivity between hi and lo limit tubes. The AFC test represents cycles off resonance for 3 KC detuning of the carrier. Sensitivity in the case of the 6-tube set varied approximately 2 to 1 and in the 10-tube set 2½ to 1. Power output remained practically the same. The r-f overload distortion increased about 2 to 1 when changing from hi to lo limit tubes while the tuning meter sensitivity decreased 3 to 1.

Assuming that the tests made represent the extreme conditions for changes due to g_m variation it may be concluded that the limits as defined in Table No. 1 are satisfactory. This statement should be qualified by an assumption that the limits used were actual factory limits. This is not known to be the case.

It must be remembered that the probability of getting all limit tubes in one set is extremely small. This probability has been worked out and the result may be of

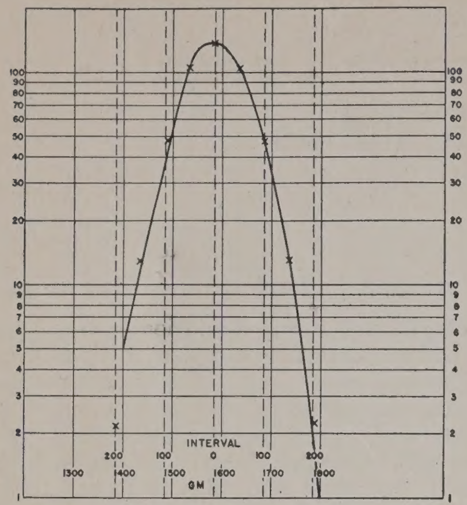

FIG. 1 GM DISTRIBUTION CURVE FOR 476 6K7 TUBES CROSSES INDICATE TRUE PROBABILITY CURVE.

some academic interest to the reader. In order to obtain a g_m distribution curve, 476 Type 6K7 tubes were tested for g_m and the curve obtained is given in Figure 1. An analysis of this curve shows its equation to be of the form

$$y = ce^{-K^2X^2}$$

where y = the number of observations

$X = g^m$ interval

The above equation is that of a true probability curve. Using $g_m = 1585$ as the average value, the constants K and X are, by calculation:

$c = 137$

$k = 0.0102$

so that $y = 137e^{-0.0104x^2}$

The exact curve represented by the above equation is indicated on Figure 1 by crosses. The fact that the g_m curve so closely approximates a true probability curve indicates good factory control over the factors which affect g_m. It means further that the engineer may in general expect that tubes will follow a true probability curve and that the distribution of g_m may result accordingly—assuming, of course, that no change in factory methods occurs to change either the constants or the symmetry of the curve. It may be seen that the limits vary around the central point of 1585 by 215 micromhos on either side or from 1370 to 1800. At these extreme points the equation of the curve gives 1.14 tubes. The probability, therefore, that a set will be provided with either all high or all low limit tubes will be, for a 6-tube set, (ignoring the rectifier).

$\frac{(1.14)^5}{(476)}$ which equals

7.96×10^{-14}

or approximately 1 in 1250 million.

On the other hand, the chance that all average tubes will be picked for one receiver is

$\frac{(137)^5}{(476)} = .00184$

or 1 in 543.

The above discussion is, of course, academic, and has no practical significance except to establish what has already been known or suspected by engineers in ge —that is, the variations in g_m between the limits im result in relatively small changes in overall set p mance, when considering the usual operating chara istics such as sensitivity, power output, etc.

The above statement will, of course, be true only the receiver contains a sufficient safety factor to pr satisfactory performance under the conditions outl A receiver having a sensitivity of 1 microvolt w perfectly satisfactory at 3 microvolts, but one w nominal sensitivity of 50 microvolts might be ques able at 150. Caution should be exercised when tubes for special purposes such as d-c amplifiers, oscillators, etc.

In the case of ultra-high frequency sets difficultie often encountered due to variations between the l used above. Two different makes of receivers with bands embracing 70 megacycles were tested with tubes in the oscillator socket. In receiver No. 1 oscillator ceased to oscillate above 58 m.c. when the limit g_m tube was used, while receiver No. 2 sto between 20 and 45 m.c. This receiver operated s factorily when average and high limit tubes were u It may be argued, of course, that the oscillator cir were not correctly designed for UHF. On the c hand, the engineer may have had no way of knowing the g_m of commercial tubes might be too low to sus oscillation in his circuit, unless by accident he us low tube for design. The probability of getting a limit g_m tube in the set, assuming the same distribu as above, is $\frac{1.14}{476}$ or 1 in 418. Thus, at least every s 418 will be equipped with a tube which will not osci over the band. This figure is probably high due to fact that the oscillator may stop before g_m reaches extreme limit. No attempt was made to arrive a more accurate figure.

We may assume that for conventional receiver op tion the present tolerances as defined by the distribu curve obtained are satisfactory. A knowledge of actual limits of g_m as known only to the tube manu turer may be very important in the design of spe circuits.

Variation In Inter-Electrode Capacity

It is well known that variations in input and out capacities of tubes will cause various degrees of alignment when tubes are changed in r-f and i-f ampli stages. This effect may be minimized by the wherever possible, of low impedance transformers in i-f stages. As a rule, the effect of alignment on the circuits is negligible as these circuits are inherently br and track the oscillator at only three points in the ba

The input capacity of converter tubes does have important bearing on the frequency range to be cover Sets designed at the present time cover a range of quencies with one set of coils which may be as high as 3. 1. This can only be obtained by very careful control o the minimum capacity. Variations of 2 to 3 mic microfarads may result in inability to align circuits the course of production. This is a hazard which is of encountered and for which there is apparently no c except very careful design or a limitation of freque range. Here again, a knowledge by the set engineer variations in input capacity is extremely valuable.

Variations in input and output capacity in au lifiers may be serious when employed in high fidelity ivers. When high mu audio tubes are used it is erative that plate and grid resistors be kept reason- low so that the effective shunt resistance is con- ably lower than the shunt capacity reactance at the er audio frequencies. Wiring capacitance must be fully controlled in receivers of this type, leaving the as the sole variable element.

he oscillator-mixer tube has an annoying habit of ging its effective input capacity with control grid bias, ing a kind of AFC action on short wave signals. If ceiver is slowly tuned into a short wave signal from low frequency side, the oscillator, once a certain t is reached, will complete the tuning itself without ner rotation of the gang capacitor. The frequency may vary from a few hundred cycles to several KC, nding on the particular tube used. This effect uces a highly unstable condition in the presence of ding carrier, as the oscillator will shift in sympathy changes in signal level, and may be thrown entirely he carrier, so that the signal can no longer be heard out retuning. This condition may be alleviated in mber of ways. A practical solution is to series feed screen so that its potential will vary inversely as the rol grid potential. A 3 to 1 improvement in the uency shift may be effected in this manner. The action will be compromised to some extent under conditions. Tests indicate that different tubes will in frequency drift as much as 3 to 1.

the matter of inter-electrode capacitance of vacuum s the engineer is supplied with maximum limits h he can use as guides in receiver development. absence of a lower limit, however, is unfortunate. is particularly true of grid-plate capacitance, as the of information regarding variations in this particular acteristic may result in serious consequences. surements on a few 6K7 tubes in the laboratory ate that the grid plate capacitance may be as low 03 mmf. The maximum value specified is .005 mmf. as long been known that grid plate capacity causes neration at high frequencies. Calculations on rtain 8-tube receiver using 6K7's as i-f amplifiers ated that the i-f stage would break into oscillation $_p$ were increased to .0056 mmf. From this it may be that a receiver might be developed in the laboratory tubes having, say, half the specified c_{gp} and provide factory i-f performance, only to break into oscillation n replaced by a tube whose c_{gp} falls on the maximum . This danger is increased when the Q of the i-f used is allowed to vary over wide ranges.

rid-plate capacity is also of great importance in high ity amplifiers. A slight variation of c_{gp} causes a change in input capacitance so that the fidelity ne amplifier will be subject to wide variations when grid plate capacitance varies. This is particularly of high mu tubes.

Heater-Cathode Leakage

um in audio amplifiers is a problem which always es the engineer concern. Filtering of low frequencies pensive and consequently it is the rule to apply no than is considered absolutely necessary. Here n we run into the problem of tube variations. When o tubes are used in single ended operation the bias ly resistor is usually heavily by-passed to prevent neration. Hum due to heater-cathode leakage is, as a rule, solved by this expedient. When used for push-pull drivers, however, these by-pass capacitors are sometimes omitted. This is believed to be a dangerous procedure considering the variations which exist between tubes. Tests were recently conducted on a receiver using push-pull drivers with no capacitor by-passing the bias resistor. Approximately 50% of the tubes tried produced objectionable hum. Commercial tubes were used, so that the inference must be that the tubes that produced hum were considered satisfactory production. It would be very desirable to provide heater-cathode leakage limits so that the set engineer will be in a position to design accordingly. The solution here is, of course, to design in such a manner that the heater-cathode circuit is of low impedance at the hum frequencies, for not to do so will make field complaints a possibility.

Gas Current

Gas current may cause a great deal of trouble in receivers if precautions are not taken to overcome the effects. The usual trouble is loss of bias, so that the solution is to keep the grid circuit resistance down to a minimum. This is especially true of output tubes when used as Class A amplifiers. Class B amplifiers, where grid current is expected should be designed with low resistance interstage transformers. Grid current in output tubes will cause a high degree of distortion and a loss of output. Gas current in high frequency amplifiers will cause r-f overload at low input levels and will result in a loss of sensitivity. Another effect which is probably not so well known is the variation of tube noise with gas pressure. It has been observed that the amount of noise produced in a receiver is often much greater than that obtained from a consideration of thermal agitation and shot effects. An investigation disclosed that a close correlation exists between gas pressure and noise. Figure 2 is a curve of noise output as a function of gas current for two 6K7 and two 6A8 tubes and indicates that the noise output increases rapidly as the gas current is increased beyond 0.5 microampere.

It is interesting to note that there is a minimum noise level, which is approached asymptotically as the amount of gas in the envelope is reduced. The curves for 6A8 tubes approach their noise asymptote at a value of gas current some 3 times greater than corresponding points for 6K7 tubes. This is because the 6A8 control grid is larger and picks up more current than the 6K7 for a given

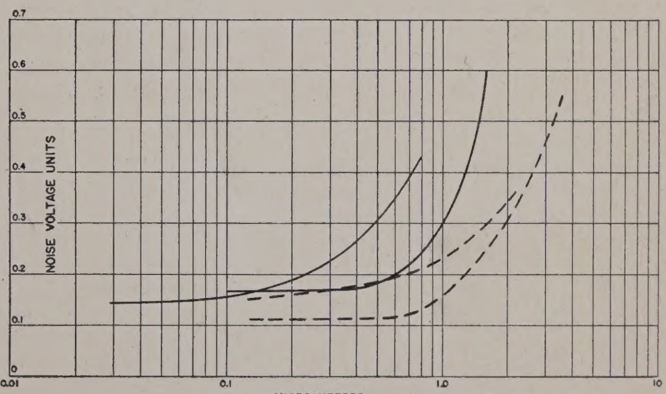

FIG. 2 NOISE - GAS CURRENT CURVES
—— 6K7
--- 6A8

gas density, on which the noise depends. In other words, the 6A8 tube is 3 times more sensitive to gas than the 6K7, and will show equal noise-voltage readings for 3 times the gas current, the gas density at these points being about equal.

A control grid voltage which produces a given signal-to-noise ratio in the 6K7 tube operated as a simple amplifier, will produce a ratio about ¼ as great in the 6A8 operated as a converter, because the conversion conductance is about ¼ the plate conductance of the 6K7 tube. Thus, the actual noise in practical uses of the 6A8 will be several times that found above in comparison with the 6K7 tube. This effect is noticeable in receivers where the converter is used with no r-f amplifier preceding it.

A more complete exhaust results in quieter tubes and a higher signal-noise ratio in radio receivers.

Figure 3 indicates the distribution of gas current in 30 tubes picked at random.

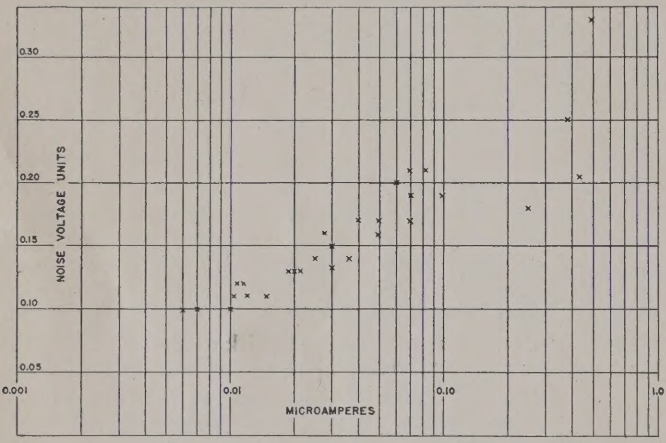

FIG. 3 NOISE-GAS CURRENT RELATIONS IN 30 6K7 TUBES PICKED AT RANDOM.

Contact Potential

Variations in contact potential may be important when dealing with certain circuits. The diode in a noise limiter, for instance, designed for suppressing noise beyond a 100% modulated signal level will actually begin limiting higher than 100% when high contact potentials exist. This occurs when weak signals are being received and is undesirable because here the limiter should be most valuable. The contact potential of the signal diode aggravates this situation. It has been found that the action of the limiter is greatly improved by the insertion of a bucking voltage in the cathode lead. Tests on a number of diodes indicate variations in contact potential from 0.2 to 1 volt.

High mu audio tubes, when used with low electrode voltages, may vary their bias between 0.5 to 2.5 volts through changes in contact potential. This range of bias voltage will produce a marked difference in operation of the receiver. The corrective is, of course, to use higher bias. Unfortunately, this is not always desirable for other reasons.

Conclusions

The scope of this paper has not permitted a detailed analysis of the items covered. Each particular phase of performance is capable of elaboration. Other less serious troubles might be included, such as effects of secondary emission, cross modulation, electrode interactions, etc., but this is not necessary for the purpose. The writer merely wishes to direct attention to the problem which confronts the set engineer arising from a lack of knowledge of performance limits for tubes. Long experience will, of course, teach him what to expect. If he has had his fingers burned by omitting a screen electrolytic, to save cost, thereby running into hum modulation in production, he will know better next time. Shutting down production lines is costly to both the manufacturer and the engineer. It would be desirable to have available in the laboratory tubes whose characteristics are representative of the high and low limits, so that some of the more frequent sources of trouble due to tube variations could be eliminated during the development period. Some laboratories are attempting to do this at the present time. Such a procedure requires close cooperation between receiver and tube engineers, for the tube people must agree to the limits to be used. The Committee on Vacuum Tubes of the RMA is to be congratulated on the preparation of the standardization material embodied in Standards Proposal No. 45, providing standardization of end of life limits for tubes. It is hoped that some effort will be made to arrive at standardized tolerances for tube performance which will be available to the Industry, so that the receiver engineer's job may be made easier and safer and the quality of merchandise maintained at a high level.

Importance of a Standard Intermediate Frequency and Reasons for the Proposal of 455 K.C. as this Standard

By G. E. Gustafson, Zenith Radio Corporation

(Editorial Note—Mr. Gustafson was appointed chairman of a Special Conference Committee on Intermediate Frequencies late in 1936, and this report is indicative of the excellent progress made in a remarkably short time. Other RMA work with The Federal Communications Commission is outlined on succeeding pages.)

Some indications of the difficulty of finding a satisfactory intermediate frequency for use in broadcast receivers can be obtained by noting the great number of frequencies which have been used by various manufacturers. During the year 1936 alone, receivers have been marketed using six different intermediate frequencies in the spectrum from 440 k.c. to 480 k.c. It is apparent from the great number of intermediate frequencies in use by the Industry, that no satisfactory solution to this problem has been obtained by anyone.

There are three major receiver design problems which can be affected by the choice of an intermediate frequency:

(1) Direct channel pickup.
(2) Tweets produced at the second harmonic of the intermediate frequency.
(3) Tweets produced by two local stations spaced by the intermediate frequency.

A questionnaire was sent to fifteen of the largest Radio Manufacturers asking for a frank expression of the difficulties which they had experienced on these three types of interference during the past year. Our Committee was pleased over the response to this questionnaire, and we received very complete reports on the five major intermediate frequencies in use: 450 k.c., 456 k.c., 460 k.c., 465 k.c. and 470 k.c. The replies indicated that none of these frequencies were even reasonably free from direct channel pickup troubles, and that this difficulty is experienced even though the receivers are carefully designed to reject code signals at the intermediate frequency. An analysis of these reports and a survey of the stations causing the interference indicated that no particular frequency in this range could be easily cleared of this interference.

The choice of a standard intermediate frequency was therefore considered from the standpoint of the other two types of interference. It appears that 455 k.c. does offer advantages over any other frequency in so far as difficulties of types two and three are concerned.

The second harmonic of 455 k.c. is 910 k.c., on which frequency there are no American stations assigned. A check of the Canadian situation also indicated that from their standpoint they would prefer to have 455 k.c. as an intermediate frequency standard rather than 465 k.c., the present standard, as they have fewer stations on 910 k.c. than on 930 k.c.

It might also be pointed out that if the Industry did standardize on an intermediate frequency whose second harmonic coincided with an American channel, that this channel would possibly become unpopular within a short time and show a decline in commercial value. This would not necessarily be true of Canadian stations, as the interference produced is much less on signals which are not local in intensity.

A frequency of 455 k.c. also appears to offer advantages on the third type of interference. An analysis of broadcast station assignment in the United States indicates that if an intermediate frequency of 450 k.c. were used, this type of trouble would be noticeable in five locations. If 460 k.c. were used the trouble would be found in six locations, and for 470 k.c. it would be found in nine locations.

If either of these frequencies were used, the tweets produced would be zero beat when the desired signal was tuned in perfectly. On the other hand, if 455 k.c. were used, the beat produced would be 5 k.c. when the station is tuned in exactly. This latter condition appears to be less troublesome.

Members of this Committee met with Members of the Engineering Staff of the Federal Communications Commission November 19th, 1936. Commander Craven had prepared for this meeting a great deal of data covering the spectrum between 440 and 480 k.c. Maps were available showing the locations of all the stations assigned in that spectrum, and also lists giving a breakdown of the number of stations assigned to each channel. Various frequencies in this range were examined to indicate what possibilities there were of clearing a channel some place in this range. Peculiarly enough, 455 k.c. appeared to offer somewhat better possibilities than any other frequency.

Commander Craven requested that the Committee obtain from the RMA an agreement that, if the Commission were able to clear code stations from this channel, that the Industry would adopt it as a standard. This assurance was obtained first at the Meeting of the RMA Committee on Broadcast Receivers, and later at a Meeting of the Board of Directors of the RMA.

It should be pointed out that this frequency has not been adopted by the RMA but will be adopted if the Federal Communications Commission is successful in providing a protected channel at this frequency.

Notes on RMA-FCC Cooperation

By L. C. F. Horle

During the past year the Engineering Division has devoted much time and effort to working with the Federal Communications Commission in the development of a basis for cooperation between these two groups whereby the Engineering Division might better study the work of the Commission with a view to guiding its own work in the development of broadcast receivers so as to best meet the severe operating conditions imposed by the system of frequency allocation and assignment as carried out by the Commission and, conversely, to so acquaint the Commission—especially the Engineering Division of the Commission—with some of the more important design problems faced by broadcast receiver designers to the end that in the work of the Commission consideration may be given to the factors involved in these problems.

In the course of this work the Engineering Division was three times represented at public hearings before the Commission and made general and specific recommendations in the matter of frequency allocation and assignment. Additionally, it has worked informally with the engineering division of the Commission on some of the more specific problems that have presented themselves.

Details of material presented to the Commission have been circulated to the entire membership of RMA during the last year and, therefore, need not be discussed in detail here. It may, however, be of some interest to review the nature of the recommendations made to the Commission.

Thus, at the hearing of June 1936, the Engineering Division strongly recommended that provision be made within the pattern of frequency allocation by the Commission for the development of television, facsimile and additional aural broadcasting channels. As for the former of these, a previous issue of the RMA Engineer has carried the recommendations made to the Commission in complete detail. Additionally, however, the Engineering Division after lengthy study and extended discussion by the special committees appointed for this purpose, made detailed recommendations for the establishment of an aural broadcasting frequency band in the so-called ultra high frequency range, more specifically, the band between 37 and 42 megacycles for use for not only the technical but the commercial development of UHF aural broadcasting, as well. It urged, also that the development of facsimile broadcasting be encouraged through the opening up of the normal broadcasting band —.50 to 1.5 M.C.—to facsimile broadcasting in the midnight to morning period when transmitting and receiving facilities are otherwise unused and that facsimile transmission at any time of day or night be provided for by the allocation of additional bands to this service in the UHF band.

In reviewing these recommendations the Engineering Division of RMA here wishes again to call the attention of all of its membership to these recommendations and to point out that work in this direction still seems to point to great possible usefulness and to urge that these projects, as suggested at the June hearing before the Commission, continue to be studied by all in the Engineering Division with the thought that the time is not far distant when the development of receiving equipment for these newer services will doubtless be called for.

In preparation for the October 5th hearing before the Commission, which concerned itself largely with matters pertaining to the more effective allocation and assignment of frequencies within the normal low frequency broadcast band, the Engineering Division made another detailed study on which it based a series of recommendations. Briefly, these concerned themselves with the characteristics of radio receivers as now in use throughout the nation and the influence of these characteristics on the effectiveness of the frequency assignment practices of the Commission. It is probably of interest to here review the fact that the extensive and detailed study of the characteristics of radio receivers made in preparation for this hearing brought to light much important and interesting information. Included in the data gathered in this work was rather complete data on normal receiver selectivity, image suppression ratios, direct i-f response, with data relating these technical characteristics to the price classes of the receivers.

Additionally, it was brought out in this hearing to what a high degree satisfactory broadcast receiver operation is dependent on the judicious assignment of frequencies in any one area especially as such frequency assignments are related to the frequency of operation of the intermediate frequency amplifier of the receiver. This matter has been the subject of study by a special committee of the Receiver Committee of the Engineering Division and a report of this work has been circulated. It may, however, be of interest to here point out that it was developed for the information of the Commission how serious can be the interference resulting from the operation of transmitters in the receiving area when the frequency or frequencies of these transmitters bear a simple numerical relationship to the frequency of operation of the intermediate frequency amplifier.

Subsequent to the October 5th hearing the Special Conference Committee on Intermediate Frequency of the Receiver Committee met on several occasions with members of the Engineering Department of the Commission and after canvassing the possibilities both of the designer's choice of intermediate frequency and the Commission's establishment of a policy of reorganization with respect to frequency assignments as related to the I.F. interference problems, the basis for an agreement as to an intermediate frequency to be used by the industry was ultimately arrived at and, by the approval of the Board of Directors of RMA early this year, has become the accepted intermediate frequency of the industry.

The readers of the RMA Engineer will doubtless be interested in the recent recommendations to the Commission by its Engineering Department on the subject of assignments to aural broadcasting in the .5 to 1.6 M.C. band as promulgated by that department on January 11, 1937. These are given in document 19557 of the F.C.C. from the summary of which the following has been abstracted:

SUMMARY

The following is a summary of the Engineering Department's conclusions, recommendations and requests for instructions with respect to the broadcast band 550-1600 kc, based upon the October 5, 1936, hearing, Docket 4063:

(1) We believe that while the engineering principles of the allocation structure of 1928 are basically sound, technical progress, operating practice and the accumulation of new data since 1928 indicate conclusively that modifications are needed and that improvements can be made which, from a technical standpoint, will result in better broadcasting service to the public.

The Engineering Department's proposals for modification would not change the 10kc separation between channels, nor would it change fundamentally the conception as to the use of both clear channels and shared channels to render service to the nation.

(2) As to the general procedure for making modification of the allocation structure, we believe and recommend that the Commission should continue its existing policy of EVOLUTION AND EXPERIMENTATION THROUGH VOLUNTARY ACTION OF APPLICANTS RATHER THAN BY ENFORCED COSTLY RADICAL CHANGES. The reasonableness of the details of the new rules and regulations could well be the subject of formal hearings after due notice is given of the effective date of the new rules.

Class	Comparison	Purpose	Night Power*	Approximate Interference Limits Night	Approximate Interference Limits Day
A	Similar to clear channel stations	To include remote rural coverage	Not less than 50 kw	.5 mv	.1 mv
B†	Similar to clear channel stations except other stations use channel so as to protect secondary coverage dominant station	To include rural coverage	10 to 50 kw	.5 mv	.1 mv
C	Similar to high power regional stations	Large metropolitan **district** coverage, as well as limited rural coverage	5 to 50 kw	2.5 mv	.5 mv
D	Similar to regional stations	Metropolitan **district** coverage	1 to 5 kw	2.5 mv	.5 mv
E	Similar to existing regional stations separated by relatively short distances	City coverage	.5 to 1 kw	4 mv	2 mv
F	Similar to local stations	City or town coverage	0.1 to 0.25 kw	4 mv	2 mv

*The power for each station of a class is to be determined individually upon showing of need and proper consideration of channel conditions with respect to interference.

†The class of stations which will use the same channel as Class B stations and protect the latter's secondary coverage, are in general Class D or Class E stations, located at sufficient distance from Class B stations to enable proper service to be rendered in accordance with the standards of good engineering practice, It may be possible in some instances to permit Class C stations to use Class B station channels.

(3) We recommend that the new rules be inherently flexible so as to permit practical adaptation of sound engineering to individual cases in accord with economic and social needs.

(4) We suggest for consideration by the Commission the use of ultra high frequencies to assist in the solution of the educational broadcast problem.

(5) We recommend six classes of broadcast stations in the band 550-1600 kc with powers as outlined in the following.

(6) We recommend that the following number of channels be assigned to the various classes of stations in the band 550-1500 kc:

Class	*Number of Channels
A	Not less than 25
B	Approximately 5
C	Approximately 14
D	Approximately 30
E	Approximately 10
F	Approximately 6
Total	90

*The foregoing numbers exclude the frequencies now assigned exclusively to Canada.

(8) We recommend that when licensing new stations, or when increasing the power of an existing station of any class on a channel assigned to such class, DUE REGARD SHOULD BE GIVEN TO THE STANDARDS OF GOOD ENGINEERING PRACTICE, particularly with reference to the interference that may be caused within the good service areas of other stations of the same class on the channel in question.

(9) We recommend that the band 1500-1600 kc be opened for Class D, E, or F stations, depending upon the policy to be determined by the Commission with respect to the number of additional stations and the type of service they should render.

(10) We recommend that all stations except Class A operate simultaneously on shared channels at night, and whenever practicable, use methods to increase service and reduce interference.

(11) We believe that two 50 kw stations separated by great distances and operating simultaneously at night on the same channel, are capable of rendering a service to a limited area, particularly if directional antennas are used. However, we do not recommend the universal duplication of all existing clear channel stations located on the coasts. We have recommended the retention of at least 25 clear channels permanently, and caution in duplicating other such channels, pending a North American arrangement.

(14) While we believe that powers in excess of 50 kw on clear channels are technically sound and are in accord with scientific progress, we recognize that social and economic factors involved in the use of 500 kw may outweight in importance engineering considerations.

(15) We feel that there is a need for increased signal intensity and have recommended that in general power increases are required to better the service of the public.

(17) We recommend against the establishment of standards of receiver selectivity and fidelity, but instead we recommend incorporation in the standards of good engineering practice the basis of receiver performance which is utilized in arriving at necessary ratios between desired and undesired signals to avoid objectionable interference.

(19) We recommend against changing the existing requirements with respect to frequency stability, modulation, harmonics and power determination.

(20) We suggest proceeding in an evolutionary manner toward the improvements in the broadcast band 550-1600 kc without endeavoring to await developments in other bands of frequencies, because we feel that the public needs the possible technical improvements in the existing broadcast service.

(21) We recommend that the present empirical standards be revised and issued in the form of "standards of good engineering practice" and used as a guide in administration and in testimony when no better evidence is available. We believe that the following is the proper trend of the resivion:

  (a) Adopt curves based on those presented by the Engineering Department at the hearing as guides to estimate service and interference under various conditions.

  (b) Retain the present ratios between desired and undesired signals for stations using the same channel.

  (c) Revise the ratios between desired and undesired signals for stations on adjacent channels. The ratios now used will be decreased to an amount to be finally determined at the engineering conference scheduled for January 18, 1937, at Washington. These revisions will permit stations of like power to be spaced geographically closer than hitherto provided in our "empirical standards".

  (d) Stations in the same city may be assigned frequencies 40 kc apart under special conditions of location and power.

  (e) While we believe that the present limit of 125 mv used in connection with "blanketing" is too small, we are not prepared at this time to accept the 1000 mv limit suggested by certain engineers at the October 5 hearing. The figure which should be used will be determined after the engineering conference scheduled for January 18, 1937, and we shall make a specific recommendation to the Division after that date.

From this brief review of the work of the Engineering Division of RMA with the Engineering Department of the Commission and the latter's most recent recommendations, it is especially to be noted that the further improvement of broadcasting is to a great extent dependent on the closer correlation of the allocation practices of the Commission and the receiver design practices of the radio industry. It was with this factor in mind that the Engineering Division of RMA recently recommended to the Board that it empower the Engineering Division to organize the continuous gathering of pertinent data on the characteristics of the broadcast receivers going into the hands of the listening public to the end that the RMA might be at all times prepared to advise the Commission as to the effect on the nation's broadcasting system of any proposed changes in that system, insofar as the effect of those changes involved the characteristics of the receivers in use.

It is with considerable gratification that the Engineering Division can now announce that the Board has approved this general plan and that an especial committee of the Engineering Division is now at work preparing specifications covering the detailed method of test to be pursued in gathering this data and that it looks confidently forward to the organization of this project to the end that ultimately a detailed cross section of the nation's broadcast receivers will be constantly and readily available.

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International Radio Interference Coordination

The Sectional Committee of the American Standards Association on Radio-Electrical Coordination (radio interference) which is sponsored by the Radio Manufacturers Association, at its meeting in February, accepted a report from its Foreign Coordination Committee of special interest to those concerned with the export of radio equipment. The scope of the work of this committee includes detailed studies of radio noise interference with radio reception, its cause and its cure. In this work it cooperates with groups of workers in this field in all of the major European countries. The work of the subcommittee on Foreign Coordination is especially directed toward the development of cooperative effort with foreign groups and its most recent report calls the attention of the American workers in this field to the progress which has been made abroad and distinguishes between the results there obtained with those gotten here and, more specifically, between the methods of interference investigation and elimination found most effective in the U. S. A. and those in most general use abroad.

Based on the work of the Sub-Committee on Foreign Coordination, the Radio-Electrical Coordination Committee prepared a presentation to be made to the next meeting of the International Electrotechnical Committee which met in Brussels, Belgium on March 15 to 20, 1937. This presentation to the international group meeting was made by a representative of one of the RMA member companies regularly resident in England who went with such detailed instructions as will bring back to the membership in the U. S. A. a more completely detailed picture of the activity abroad than has previously been available.

The activity of the groups abroad tending toward the establishment of limiting permissible radio interferences —where such interference is generated in electrical equipment of all kinds—will be found to be of special interest to all of the membership of RMA interested in the exportation of receiving equipment, especially to those exporting equipment to the Central and South American countries, where the influence of the work of foreign workers in the interference field and that of workers in the U. S. A. meet and probably largely determine the influence of that sort of interference on the operation of radio receiving equipment.

A later report of the Radio-Electrical Coordination Committee will doubtless make available to all American groups interested in the subject more detailed information as to the work being done abroad in this field.

Cross-Talk Interference

By C. E. Kilgour, Crosley Radio Corporation

The term "cross-talk" has been used to designate communication interference of several types. However, in radio it has been specifically used to indicate interference due to non-linearity of a device in a receiving circuit. A few years ago when first it became the practice to control the sensitivity of a receiver by increasing the bias on the radio frequency amplifying tubes this type of interference was a serious problem. The difficulty has been largely obviated by the development of the super control, variable mu or exponential types of vacuum tubes, although commercial tubes today are not always entirely free from fault in this respect.

A few years ago in Cincinnati complaints were received that the modulation of a powerful local station might be heard when a radio receiver was tuned to a second local station thus producing a mixture of the two modulations. Upon checking the complaint it was found that reduction of the antenna length to practically nothing did not eliminate the difficulty. If the cross talk had been due to non-linearity of the first tube such a decrease of signal strength should have removed the effect. It was found that a portable battery receiver with a very small antenna would also receive the same cross-talk.

After some experimenting and theorizing it was concluded that the cross-talk must have been produced in some circuit external to that of the receiver. This conclusion has been amply verified. It has been conclusively shown that power wiring, telephone wiring, metallic building structures and the aerial and ground sytems of radio receivers may constitute pickup systems with dimensions suitable for producing considerable potential from broadcast signals and these may incorporate poor connections or bad contacts constituting non-linear devices and thus produce the various cross-talk effects.

Non-linearity may be of such a nature that it can be expressed by a power series employing only first and second degree terms. When such non-linearity is present the cross-talk will consist of modulated second harmonic frequencies and spurious or ghost signals of the sum and difference frequencies of any two signals present, in which case the new frequencies will have the modulation of both signals. In case a third degree term is required to express the non-linearity, modulated frequencies of the third order harmonic will be found as well as spurious frequencies which are equal to twice one of the signal frequencies plus or minus a second with modulation due to both signals and, in addition, frequencies which may be the sum or difference of three signal frequencies with modulation due to all three signals. Also the modulation of one signal may be transferred to that of another carrier. This last effect is the one which is usually noticed because it interferes with local reception. It is also possible for third order effect to cause modulation distortion of the received signal even though no other signal is present to give cross products. The non-linearity may be of such a nature that effects higher than the third order are present. In this case the number of possible spurious frequencies is greatly increased. Since the alternating supply voltage, usually sixty cycles, may be present in the structure exhibiting the non-linearity, there may result sixty cycle modulation of signals either on normal or spurious channels.

Cross-talk interference generated externally of the receiver is usually not a common cause of complaint with field strengths much under one volt per meter although occassional cases will occur with field strengths of the order of two or three tenths of a volt per meter. Electric wires for lighting circuits will be found to be one of the commonest sources of this type of interference. This is particularly true in districts where the wiring is old and where neutrals are not grounded. Difficulty may be caused by poor connections in fuse blocks, attachment sockets and electric light switches. Trouble is often experienced due to poor connections at ground clamps which are frequently found to be corroded. Water or gas pipe lines crossing each other and making light connections may cause trouble. Interference has been found to be due to poor insulation of lead-in straps used under window sashes. If this insulation is badly worn so that the lead-in conductor makes a poor contact to metal sash or weather stripping serious interference may be caused.

When cross-talk is present in a locality the source may be found by attaching a small portable antenna to a shielded portable battery receiver and exploring the premises, holding the antenna close to various suspected structures in turn. If the antenna can be constructed in the form of a loop so as to show directional properties this will be of some advantage in pointing out the source of interference. During this procedure the receiver is tuned to one of the spurious signal frequencies which may be calculated from the frequencies of the stations involved in the cross-talk. For instance, if a station at 550 Kc. is cross-talking with a station at 700 Kc. one of the spurious signals expected would be found at 850 Kc. This is twice 700 minus 550. If the receiver is tuned to this spurious signal it responds only to the waves generated by the source of cross-talk which may thus be readily located.

Sometimes the cross talk may appear to radiate from every metallic structure on the premises. In this case a general clean-up is initiated. It may be that after all piping is separated and all ground and other connections are made good, that cross-talk persists, indicating that interference is originating outside the building and is being conducted in by means of the electric service wires. In such a case opening the service switch at the point where the lines enter the building may cause a very material reduction in the cross-talk picked up by the portable receiver. In this instance the difficulty may be look for on the exterior lines themselves. Poor splices at service branches, poor contacts at cut-outs and poor transformer grounds may cause the difficulty. It is also possible that the cross-talk may be originating in an adjacent building and may be transmitted to surrounding buildings by way of the electric wiring. It is sometimes necessary to clean up all the houses in a district in order to get rid of this interference.

High voltage transmission lines may be sources of cross-talk. Some of these lines have a grounded guard wire located above the circuit wires. This guard wire passes through grounded metal rings on each pole making only a loose contact. Some available evidence appears to indicate that this form of construction is responsible for cross-talk difficulties.

It thus appears that a type of interference unthought of but a few years ago may be a serious factor under conditions of substantial field strengths. However, it may be said that the causes of this type of interference can be removed. In districts where the service wiring is all underground and conduits and piping are properly grounded, external cross-talk is practically non-existent. In other words, where elevated metallic structures are in proper condition no trouble is experienced.

The Handbook of Interior Wiring Design

Some two years ago a movement was organized by those concerned with the continued extension of the use of electric power. This movement had for its object the encouragement of the better use of electric power especially for residential and commercial purposes. It was early recognized that progress in the desired direction could best and most rapidly be made by a campaign of education of all concerned with those phases of the building industries involving the use of electric power. That educational project was referred to groups of technical experts of the several branches of the electrical industries who have prepared the "Handbook of Interior Wiring Design" which has been circulated to the membership of R.M.A.

The Engineering Division of the Radio Manufacturers Association under the chairmanship of Dr. W. R. G. Baker contributed to the work of these technical groups and, in fact, supplied the personnel of the group which prepared the sections of the book devoted to radio. Included on this committee were Messrs. E. T. Dickey, Virgil M. Graham, L. C. F. Horle, and A. F. VanDyck. The following organizations sponsored and contributed to this Handbook: Artistic Lighting Equipment Association, Edison Electric Institute, Illuminating Engineering Society, International Association of Electrical Inspectors, National Electrical Contractors Association, National Electrical Manufacturers Association, National Electrical Wholesalers Association, and the Radio Manufacturers Association.

It will be of interest to note that the Handbook discusses the general and specific details of the desirability of adequate wiring in homes and other structures. It discusses in considerable detail the absolute need for extensive wiring and the provision of power outlets, which should be adequate from the standpoint of number and location.

In general, it attempts to provide such education as to the basis of the specific recommendations that are made as to indicate the rationale of the recommendations and to provide for the extension of the rational basis for the determination of the adequacy of wiring and outlets to cases not specifically covered by the detailed recommendations.

In each of the sections of the Handbook, emphasis is placed on the need for provision for the operation of radio receivers, not only in so far as the provision of power outlets is concerned but, more specifically and in considerable detail, with reference to the need for provision of antennas and antenna "down leads" concealed within the structure in the process of construction.

Along with these data of especial importance in connection with the more adequate provision for radio receivers in all forms of building construction, the Handbook includes important data as to conductor loading and similar power data. General information as to lighting and power wiring serve to make the Handbook of tremendous usefulness to all concerned with electrical problems in the field of building construction.

It is believed that the sections devoted to radio will serve well to rationalize the viewpoint of the architect, builder and contractor with respect to the problems presented by the need for proper provision for radio receivers in all forms of building construction, including some of the details of the financing of proper construction. These sections also point out the possibilities of some very useful standardization work on antenna systems and receiver input designs.

Report of Meeting of Sub-Committee 3 of Committee D-9 of the American Society for Testing Materials

Held at Pittsburgh February 25, 1937

While a general report of the work done by this sub-committee at the most recent meeting at Pittsburgh will probably be circulated later, this brief report has been prepared for the membership of the RMA Engineering Division in order that those phases of the work of the sub-committee of most interest to the radio manufacturers may be more promptly brought to their attention.

It will be remembered that the work of the sub-committee previous to the Pittsburgh meeting had resulted in the preparation of tentative specifications for laminated phenolic material for radio uses and that these tentative specifications had already been circulated to the membership of the Engineering Division of RMA, amongst others, for comment and criticism. The meeting at Pittsburgh, therefore, provided for the general examination and discussion of the comments on the specifications resulting from this circularization of them.

It will be of interest to note that there were two general types of criticism of the tentative specifications received from the membership of RMA. The first of these was directed toward the attempts to define the "punching properties" of laminated sheet as included in the specifications. It will be remembered that this property was defined in terms of "good punching practice" in which the relationship between the thickness of the sheet and the minimum size of punched holes on the one hand, and on the other hand, the relationship of the edge of the punched piece and the edge of the sheet from which it is punched, were resorted to in order to define good punching practice and thus to define the punching qualities of laminated phenolic sheet.

These definitions were found too loose by two members of the RMA group since, as was pointed out, actual punching practice in the radio industry is more severe in its requirements as to the punching qualities of the laminated sheet than the "good punching practice" specification set up in the specifications.

Additionally, criticism was made of the water immersion conditioning of test specimens of laminated sheet before the measurement of its electrical properties, as given in the specifications.

Both of these matters were the subject of an extended discussion by all interests present at the sub-committee meeting. This discussion brought out the following:

The definition of the punching qualities of laminated sheet stock in terms of "good punching practice" as defined in the specification was made unavoidable by the lack of completion of the work being done by other sub-committees in correlating various hardness determinations, i. e., Rockwell and others, and the "punchability" of sheet stock; and that the definition of this characteristic in terms of "good punching practice" must be viewed as a purely temporary expedient pending the availability of a sounder and a more generally acceptable definition.

It was further brought out that while substantially all manufacturers of laminated phenolic sheet were fully appreciative of the fact that the radio industry has provided successful designs including punching details markedly more severe than those given in the specifications, it was not felt that it would be generally satisfactory to include in the specicifications these more severe specifications as defining **the only form** of laminated sheet of interest to the Radio Industry.

It was suggested, therefore, and found generally satisfactory amongst those in attendance to add to the specifications a paragraph indicating that the specifications of "punchability" are, in fact, merely a minimum standard and that any higher degree of this characteristic be the subject of agreement between the manufacturer of the laminated phenolic sheet and the radio manufacturer to whom he supplies it.

The second point of major interest to the radio group concerned the matter of conditioning of specimens for radio frequency measurement by immersion in water for a stipulated period. It was pointed out that under certain conditions such conditioning is more severe and under other conditions less severe than the conditions of moisture and humidity under which the sheet is actually used in service. Here again the difficulty was found to reside in the fact that other sub-committees working on the problem of conditioning for humidity testing had not yet progressed sufficiently to supply specifications for conditioning that would sufficiently closely realize the conditions of practice to justify their inclusion in the specifications. It was reported that work in this direction is progressing and that the sub-committee can ultimately provide specifications for humidity testing of laminated sheet that will doubtless eliminate the objections raised to the immersion test.

Wholly aside from the discussion of the objections made to the specifications by the RMA group, it is to be reported that much discussion was had of the methods to be used in the determination of the r-f characteristics of laminated sheet. In this, two schools of thought seemed to have developed in the committee: one that favors the use of the standard ASTM method of making such measurement; and a second that favors the use of other types of measuring apparatus more generally available within the radio industry. The former of these has in mind the use of specimens in the form of strips to be subjected to dielectric stress parallel to the laminae while standing between large flat plates which comprise a portion of the tuned circuit in which effective resistance is measured by the substitution or other simple method. The latter group has in mind the use of specimens in the form of thin washers assembled on a cylindrical metallic expanding mandrel and enclosed in a cylindrical metallic contracting housing, the two conducting elements of which become the plates of a capacitor the loss or resistance of which is then measured in the commonly available "Q-Meter" type of resistance measurement arrangements.

No final decision was arrived at in this matter but it should be reported that common radio laboratory practice is being given detailed consideration by the committee in connection with the specifications.

It may be further reported that amongst the manufacturers of laminated sheet there was a definite feeling that the precision of maintenance of dimensions of sheet stock as given in the specifications was likely to result in considerable difficulty and without any compensating advantages evident to those present. This, too, will be given further discussion and will be the subject of further circularization in the event that it is found desirable to modify the values of allowable variations in sheet sizes as given in the specifications.

As a result of the extended discussion at the sub-committee meeting on February 25th and the further work that will be done in the development of the specifications in the next several months, it was felt that something more nearly approximating the final form of generally acceptable specifications would be available sometime in April. It was planned by those representing RMA at this sub-committee meeting to have these later specifications available for circularization to the membership of the Engineering Division of RMA prior to the May meetings in conjunction with the IRE Convention and to arrange for general, and it is hoped, final discussion of them at the May meetings after which a report will be made to the ASTM meeting in June.

LAWRENCE C. F. HORLE

Forthcoming RMA Committee Meetings

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The Twenty-fifth Anniversary Convention of The Institute of Radio Engineers will be the occasion for important meetings of several Committees of the RMA Engineering Division. The Committee on Broadcast Receivers under the Chairmanship of Mr. E. T. Dickey will meet, and several sub-committees of The Committee on Component Parts will hold sessions under the guidance of Mr. L. C. F. Horle. The second gathering of The Board of Editors of The "RMA Engineer" is also scheduled. All members of these committees are urged to plan to be present so that the maximum in accomplishment can be realized.

The meeting of The General Standards Committee originally planned for this time has been postponed for two or three months to enable several important proposals, now pending, to be completed so that the final action need not be delayed until November.

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Adler Manufacturing Company.
Aerovox Corporation.
Allen-Bradley Company.
American Electro Metal Corporation.
The American Steel Package Company.
Amperite Corporation.
Arcturus Radio Tube Company.
Automatic Radio Manufacturing Company, Inc.
The Bead Chain Manufacturing Company.
Belmont Radio Corporation.
Bentley, Harris Manufacturing Company.
Birnbach Radio Company, Inc.
Bliley Electric Company.
William Brand and Company.
Walter C. Braun, Inc.
C. F. Cannon Company.
The Capehart Corporation.
Centralab.
Champion Radio Works.
Chicago Telephone Supply Company.
Chicago Transformer Corporation.
Cinch Manufacturing Corporation.
Clarostat Manufacturing Company, Inc.
Colonial Radio Corporation.
Continental Carbon, Inc.
Cornell-Dubilier Corporation.
Corning Glass Works.
Cornish Wire Company, Inc.
Corona Radio and Television Corporation.
Crescent Insulated Wire and Cable Company.
The Crosley Radio Corporation.
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Ken-Rad Tube and Lamp Corporation.
Kester Solder Company.
Lenz Electric Manufacturing Company.
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The Muter Company.
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National Union Radio Corporation.
Noblitt-Sparks Industries, Inc.
Oak Manufacturing Company.
The Ohio Carbon Company.
Operadio Manufacturing Company.
Patterson Radio Company.
Philadelphia Storage Battery Company.
Philmore Manufacturing Company, Inc.
Pierce Airo, Inc.
Pilot Radio Corporation.
Quality Hardware and Machine Corporation.
Quam-Nichols Company.
The Radiart Corporation.
Radio Condenser Company.
Radio Research Company, Inc.
Radio Speakers, Inc.
Raytheon Production Corporation.
RCA Manufacturing Company, Inc.
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REA Magnet Wire Company, Inc.
Reliance Die and Stamping Company.
Remler Company, Ltd.
The Rola Company.
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The Sparks-Withington Company.
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Spaulding Fibre Company, Inc.
Speer Resistor Corporation.
Stackpole Carbon Company.
Standard Transformer Corporation.
Stewart-Warner Corporation.
Stromberg-Carlson Telephone Manufacturing Company.
Supreme Instruments Corporation.
Synthane Corporation.
Triad Manufacturing Company, Inc.
Tung-Sol Lamp Works, Inc.
United American Bosch Corporation.
Utah Radio Products Company.
The Webster Company.
Wells-Gardner and Company.
Weston Electrical Instrument Corporation.
Zenith Radio Corporation.

R. M. A. Technical Data Bureau

■ ■ ■

The Board of Directors of R. M. A. at its meeting on September 29th gave its approval to a plan for the establishment within the Radio Manufacturers Association of a Bureau, the function of which will be to maintain a continuous record of the characteristics of the broadcast and television receivers being produced by the membership of the Association and to develop from that record a detailed knowledge of the broadcast and television receivers in the hands of the public at all times, as well as to have always currently available such complete data on the characteristics of broadcast and television receivers both current and obsolete as to allow of the recognition of the trends in the developments made by the industry. Experience has shown the tremendous value of the centralized accumulation of product performance data in many fields and, as a matter of fact, many segments of American Industry have for their own purposes long since provided for precisely such continuous maintenance of data on the product of that industry as is now contemplated by the Radio Industry. In the radio field, such information as will ultimately be made available will, of course, be of outstanding value to the regulation of our nationwide system of broadcasting as carried on by the Federal Communications Commission. Indeed, it will be remembered that the project here discussed was first suggested by the difficulties which the Association faced last year in its desire to be of assistance to the Communications Commission in its contemplated reorganization of its plan of frequency allocation and assignment. The successful operation of the R. M. A. Technical Data Bureau will make quite impossible the duplication of so difficult a situation as was then revealed.

There is, however, at least equal value to be found in the contemplated Technical Data Bureau for purposes other than of the administration of the radio broadcasting facilities of the nation. Foremost in this is the basis for the maintenance of improved public relations afforded the Association by a continuously available and intimate knowledge of the nature of its product in the hands of the public. Additionally and of great importance is the fact that the Association, itself, can doubtless best guide the direction of its technical progress only by a detailed knowledge of its past progress and its current trends. The determination of both these factors has, in the past, been the problem of each individual manufacturer and, in view of the economic and other limitations imposed on the work of any one individual manufacturer, has been surprisingly successful in its accomplishments. By the pooling of data as is contemplated by this project, however, not only will unquestioned economy of time and effort result, but the greater completeness of information made available through the sub-division of effort which is basic to the plan, will provide the basis for a more precise and detailed knowledge of the technical progress and accomplishments of the industry than has ever yet been anywhere available.

The first step in the plan is—or was—the determination of such of the characteristics of broadcast receivers of major importance to the interest of the public and the industry as can within the limits of the equipment and personnel available in the industry for their determination, be most promptly and usefully determined, tabulated and disseminated.

This was referred last January to a special Committee on the Accumulation of Broadcast Receiver Characteristic Data for investigation and report. The work of that committee, carried on in close conjunction with the Committee on Broadcast Receivers, resulted in a series of recommendations as to the data to be accumulated in this project and has, in addition, included much of the technical matter the definition of which is essential to the establishment of the project on a sound basis. There is given below an abstract from the report of the Committee on the Accumulation of Broadcast Receiver Characteristic Data enumerating the elements of the receiver data which will be accumulated.

1—Identifying Data.

A. Type or other arbitrary identifying number or symbol of the receiver mechanism, including in addition to receiver chassis, such power amplifier, loud speaker power supply units, remote controls, etc. which may comprise the entire receiver mechanism assembly.

B. Number of wave bands of reception provided by the receiver.

C. Number of variable condenser sections included in radio-frequency circuits of the receiver.

D. Number of tuned circuits and the frequency at which they operate in the intermediate frequency signal circuits of the receiver.

E. Number and type of tubes, their place and function in the circuits of the receiver.

F. Special features of the receiver, such as A.F.C., A.S.C., automatic tone compensation, volume expansion, etc.

2—Price and Quantity Data.

A. Type or other arbitrary identifying number or symbol of complete radio receiver assembly or assemblies including the receiver mechanism as identified in 1.

B. Quantity in which each assembly listed directly above has been manufactured.

C. Price at which each of the assemblies listed above have been advertised for sale to the public.

3—Performance Data.

A. Frequency limits of the several tuning ranges of the receiver.

B. Sensitivity of the receiver measured near the extremes and the centre of each of the frequency bands of the receiver.

C. Selectivity of the receiver measured at 1000 K.C. by the single signal method.

D. Selectivity of the receiver measured at 1000 K.C. by the two signal method.

E. Maximum Power Output without regard to distortion at 30% signal modulation.

F. Electrical Fidelity.

G. Automatic Volume Control Range.

H. Spurious response sensitivity (image response, I.F. response, etc.)

It will be noted from the above that the required data includes, in addition to uneqivocal identification of the equipment involved, data on the quantity in which each model is manufactured, the price at which it is offered to the public and, finally and in detail the pertinent performance characteristics of the equipment itself.

In addition to the decision as to the pertinent receiver characteristics, the Committee was impressed by the fact that it was essential that it recommend in considerable detail the methods and equipment to be employed in the gathering of the technical data in the interest of avoiding insofar as that is humanly possible any lack of consistency between sets of data gathered at different times and at different places. It was, however, faced with the fact that while a considerable degree of standardization in methods and equipment for measurement in the receiver field had been developed, the rapid progress made in receiver design within the last few years had left much to be desired in the published standards generally available to the engineering forces of the Industry. For this reason it directed much of its efforts toward the acceleration of the work of standardization in this field and was thereby able to include in its recommendations to the Board specifications as to methods and equipment which have been long under consideration by the appropriate standards committee of the I. R. E. and which will, most probably, soon become national standards.

These are far too lengthy and detailed to justify inclusion in this report of the present status of the project, but they will, however, be included in announcements to the engineers of the Association incidental to the initiation of the work of the Technical Data Bureau. It will be of interest here to consider some of the details of the operation of the project which have been approved by the Board of Directors of R. M. A.

In general, the function of the Technical Data Bureau will be purely one of accumulation of the data, the classification and dissemination of tabulations, generalizations and reports, of and from the data as may be authorized by the Board. It will be the responsibility of each of the radio receiver manufacturing members of the Association to gather the pertinent data on each model of his production as early as possible in the production season.

The data so gathered is to be recorded on a standard data report form supplied by the Technical Data Bureau and is then to be forwarded to the Bureau for further use there. The Data Bureau, upon receipt of the data and after eliminating all recognizable reference to its source, will transcribe it in such form as will maintain the Bureau records in such condition that reclassification for purposes of any legitimate inquiry may be met most promptly and readily.

For the purpose of the regulating body a simple classification of characteristics against price and quantity will probably serve in the immediate future as it has served in the past to assist the regulation of radio broadcasting to the best interests of all concerned.

For the purposes of the industry, however, other classification will doubtless be necessary such as, for instance, to establish the average or optimum characteristics in any price class or the establishment of quantity versus technical characteristics, or even the ultimate establishment of relationships involving geographical distribution and technical characteristics.

As experience is acquired in the operation of this project and as practical television operation and production develops, the purposes of the industry will doubtless require that the additional testing techniques and data be included in the operations. Such additions and extensions have already been contemplated in the formulation of the project and can be expected, therefore, to offer no serious impediment to its further development.

More specifically as to the operation of the Bureau, itself, the transcription of the data will be done, as far as possible, through the employment of statistical methods and equipment, not only in the interest of making its interpretation from many viewpoints quickly and precisely possible but of maintaining the confidential nature of the data. Indeed, it is planned that only two individuals have access to the uncoded original data, i.e., the individual responsible for the operation of the Bureau and one other who will at some time during each year make an audit of the year's accumulation of data; the original data at all times other than the brief period required for coding and transcription being carefully protected against loss or unauthorized access.

It is believed that now that the project has been approved by the Board, it should be put into operation as quickly as possible to the end that data on the now current models of the industry may be gathered and the first report on them made available before the close of the year.

With this in mind the entire plan of the establishment and operation of the R. M. A. Technical Data Bureau will be presented to the meeting of the Engineers of the Radio Industry at the Joint R. M. A.-I. R. E. Rochester Fall Meeting and their cooperation is earnestly solicited to the end that this large project may be gotten promptly and successfully under way.

Figure of Merit for Television Performance

A. V. Bedford, R C A Mfg. Co., Inc., Victor Division

The best known resolution test chart is probably that used by optometrists in testing eyes and fitting spectacles. It consists of several horizontal rows of random letters of the alphabet, each row being of smaller type than that immediately above. Arbitrary numerical rating can be given to the picture transmitting system, which in this case is the patient's eyes and spectacles, by observing the height of the smallest row of letters which may be read accurately at a specified distance.

Such charts have been used to test television systems but have been discarded due to the following reasons:

1. Some letters of a given height are easier to discern than others, causing inconsistent readings.
2. The reading gives no indication of relative horizontal and vertical resolution of the picture since legibility depends upon both vertical and horizontal resolution.
3. Sequence of letters are indeliberately memorized resulting in erroneous readings.
4. No accurate evidence is available to indicate the primary limiting factor, i.e., whether it is defocusing, imperfect interlacing, inadequate frequency response, or inadequate number of scanning lines.

At a very early date it was found that a pattern consisting of uniformly-spaced parallel black and white vertical bars could be used at variable distance from the pick-up device to determine limitation of horizontal resolution due to frequency response. When such a pattern is transmitted by a system using horizontal scanning, each pair of black and white bars causes the generation of a single cycle. Hence, by counting or calculating the number of bars required to equal a certain dimension in the transmitted picture at the greatest distance from the camera at which the bars can be distinguished, the frequency limit of amplifiers, etc., may be readily calculated.

If the same pattern is then rotated so that the bars are horizontal and the distance for resolving is adjusted again, the number of bars required to fill a similar distance in the transmitted picture indicates in similar units the vertical resolution of the picture.

The use of this chart obviously required considerable manipulation and checking in order to obtain accurate readings. These difficulties were overcome by the design of a chart such as that shown in Figure 2, which is used at present.

The Tapered Wedge Chart

Several intermediate chart designs were used in the intervening eight or ten years of television development. One of these, which was designed by Mr. T. V. DeHaven and shown in Figure 1 is still used due to its great ease in reading quickly. It was made for use with a picture system having a 6/5 aspect ratio. In order to facilitate the adjustment of the pattern at the proper distance from the camera to completely fill the picture screen, two large circles are provided, one having a diameter equal to the height of the screen and the other having a diameter six fifths as great or equal to the width of the picture screen. Two sets of test bars at right angles are provided. The vertical set is used for measuring horizontal resolution and the horizontal set is for vertical resolution. The vertical set consists of 19 alternate similar black and white bars which are spaced relatively far apart at the top and gradually less distance apart at the bottom, thus making a wedge shaped figure. Along the side of the figure are calibration numerals 110, 125, 200, 300, 400, 500 etc. which are intended to be legible when seen through any television system it is desired to test. The calibration numerals are read in units which may well be called "resolution bars" and indicate the number of bars (both black and white) having the width indicated which would be required to fill a distance equal to the **height** of the entire picture screen.

Similarly, the horizontal set of bars forms a wedge which extends across the screen with the bars converging to a point at the right hand side. This wedge figure is broken where it crosses the vertical wedge but no portion of it is lost. The calibration is identical to that on the vertical wedge, so that equal readings on the two wedges indicate equal picture resolution per inch along the screen surface without regard to the aspect ratio.

Sectionalized Resolution Chart

The test chart which is now considered most useful for over-all resolution check is shown in Figure 2. It consists of 12 substantially identical major squares arranged in three horizontal rows to form a rectangle having a 4/3 aspect ratio to conform with the present television standards. The squares have been assigned identifying numbers, 1 to 12, proceeding from the upper left hand corner, left to right. Each major square consists of four minor squares of equal size but different patterns. Each major square contains a complete vertical wedge of thirteen tapered bars which start in the upper right hand minor square with a resolution calibration of 100 "resolution bars," graduates to 150 at the middle and 200 at the bottom of that minor square. The wedge continues in the lower left hand minor square with 200 at the top, 250 in the middle and 300 at the bottom. The bars of the wedge are slightly curved so that a linear relation between distance along the wedge and resolution is obtained, facilitating intermediate readings. The horizontal wedge is similar, beginning with 100 at the left hand side of the upper left minor square and finishing with 300 in the lower right hand square. Numerals 1, 2 and 3, standing for 100, 200 and 300 are located on sample major square No. 6 to indicate the calibration in "resolution bars." On both vertical and horizontal bars the calibration indicates the number of bars of the indicated width that would be required to fill the screen vertically.

The area surrounding the "wedge" in the two lower minor squares of each major square is divided into four smaller areas which have been cross-hatched to produce the effect of different half tones from black to white. The value of these shades are marked in the sample major square number 3, as fractions which indicate the shading as a portion of complete black.

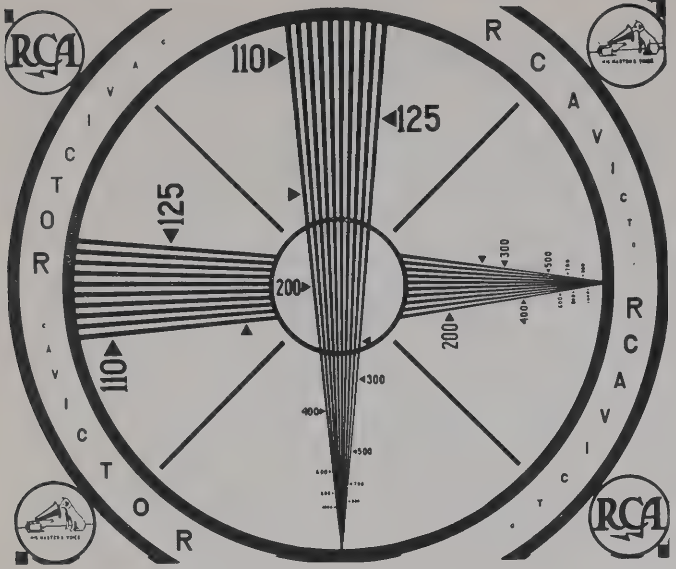

Fig. 1

Use of the Sectionalized Chart

The sectionalized resolution chart as shown in Figure 2 can be used to determine facts covering the quality of a television system in the following respects:

(a) Vertical Resolution in any or all of the 12 portions of the screen.
(b) Horizontal Resolution in any or all of the 12 portions of the screen.
(c) Upper frequency cut-off.
(d) Character of high frequency "hang over."
(e) Focus of pick up lens, and size and sharpness of "Iconoscope"* and "Kinescope"* scanning spots.
(f) Over-all Resolution Figure of Merit.
(g) Half tone transmission and saturation.
(h) Shading.
(i) Interlacing.
(j) Aspect ratio of transmitted picture.
(k) Deformation due to poor trapezoid correction or other defects.
(l) Vertical deflection linearity.
(m) Horizontal deflection linearity.

In making any resolution test the apparatus should be adjusted so that black, white and at least two intermediate shades between can be distinguished in the test chart, and preferably in the particular major square being read. The object of this requirement is to be sure that a false illusion of good frequency response is not being obtained by excessive amplification at certain frequencies being suppressed by saturation in the system.

The vertical resolution (a) may be read in any one of the twelve major squares by observing the point along the horizontal wedge at which the bars become substantially indistinguishable. In general, vertical resolution is independent of frequency characteristic, but is limited by optical focus, interlacing (i) and size of "Iconoscope" and "Kinescope" scanning spots (e). If these factors are not limiting, the ultimate limit is reached due to the scanning lines being random in location with respect to the converging resolution bars in the wedge, producing beating effects. Observers have generally set this limit at between 64 and 75 bars resolved for each 100 scanning lines.

Horizontal resolution (b) in any one of the twelve squares may be read in the vertical resolution wedge. This reading is definitely limited by the high frequency

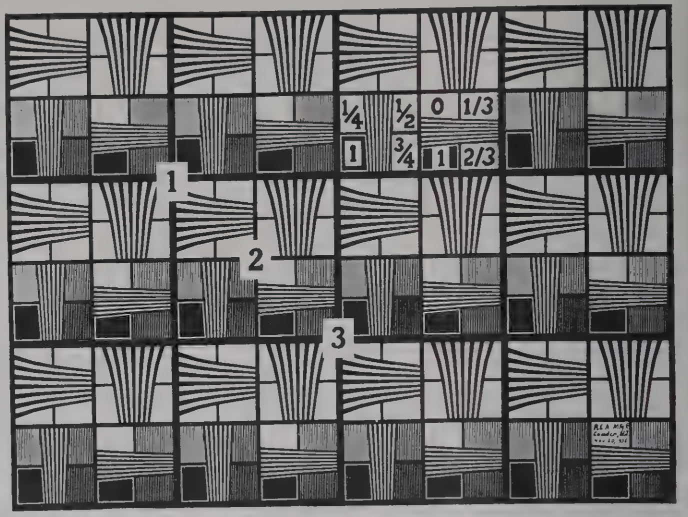

Fig. 2

response (c) of the transmission system since scanning across the vertical wedge produces a high frequency. Since only the fundamental frequency generated is required for adequate identification of the bars, a cycle is generated by each two bars (black and white). The generated frequency is:

$$f = \frac{HanR}{2} \frac{1}{(1-B)}$$

where H is the reading on the resolution wedge, a is total number of scanning lines, n is frame repetition frequency, R is aspect ratio and B is the percent of the time (expressed as a fraction) at the end of each horizontal line to accommodate return of the scanning spot to the start of the next line. (The equation assumes uniform speed of scanning along the line.)

In certain improperly adjusted systems a high frequency "hang over" (d) will be produced in the received picture immediately following in time, i.e., to the right hand side of a certain section of the resolution wedge. Such a "hang over" (d) which may be visible for one to six or more cycles is generally due to a sharp peak in the frequency response at the frequency corresponding to that portion of the wedge.

In making vertical and horizontal resolution measurements, certain tricks may be employed to separate the several factors which limit the resolutions reading. For example one way to test for size of scanning spot in the "Iconoscope" (e) and optical focus on the "Iconoscope" plate is to temporarily reduce the amplitude of scanning in the "Iconoscope" so that only a small section of the "Iconoscope" plate and test pattern is scanned. This results in an enlarged view of a portion of the test pattern being reproduced on the receiving screen and generally permits the observer to properly discount response and excessive size of "Kinescope" scanning spot.

The Over-all Resolution Figure of Merit (f) is intended to be a numerical value which indicates on a relative basis, the total ability of the picture to convey information. It may be given as the total number of black and white dots which could be put in a scene to be transmitted with random location relative to the position of the scanning lines, and which could all be separately identified and located in the received picture. If this should be measured directly it would require transmitting a pattern consisting only of black and white dots. The dots might be arranged alternately in staggered rows somewhat like a checker board. However due to all areas of the picture not having identical resolution the dots should have different size and spacing in different areas in order to be just distinguishable in all areas.

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*—Trade Marks "Iconoscope," "Kinescope," Reg. U. S. Pat. Off. by R. C. A. Manufacturing Company, Inc.

"An Experimental Television System" by R. D. Kell, A. V. Bedford and M. A. Trainer—Proc. of IRE Vol. 22, No. 11, Nov. 1934.

The sectionalized resolution chart as shown in figure 2 can be used to measure the Over-all Resolution Figure of Merit (f) with reasonable accuracy. It is assumed that the vertical and horizontal resolution readings obtained in each major square may be considered to be substantially the effective average values throughout the square. Then the product of the vertical and horizontal readings divided by 3x3 or 9 would represent the number of resolvable dots for that particular square since the resolution chart is calibrated in **each** direction in terms of the number of bars required to fill a distance equal to three times the height of one square. Then the Over-all Resolution Figure of Merit is:

$$m = \sum \frac{HV}{9}$$

for 12 squares

where H and V are the horizontal and vertical resolution readings respectively. A figure of merit obtained in this manner may serve as a specification of performance or it may serve as a means of measuring progress in development of an experimental or commercial television system.

Since each major square of the chart has two different sets of calibrated shaded areas between black and white, the chart is helpful in judging the fidelity of half-tone (g) transmission. Also the calibrated half-tone areas may be useful as a comparative standard for evaluating the spurious output signal of the "Iconoscope," which is known as "shading" or "dark spot" (h). However, no scheduled procedure for these tests has been established.

The test chart has a well defined 4/3 aspect ratio which is useful in checking picture aspect ratio (j). It also has abundant vertical and horizontal equally spaced straight lines which often is helpful in making either a quick rough check or a careful measurement of any deformation of the received picture due to stray magnetism, poor deflecting yokes, improper "Iconoscope" mounting, inaccurate compensation for the tilt of the "Iconoscope" plate (k) poor vertical (l) or horizontal deflecting (m) saw-tooth wave or other causes.

■ ■ ■

The Work of the Sectional Committee on Acoustical Measurements and Terminology of the American Standards Association

By Hans Roder, General Electric Company

The American tentative standard acoustical terminology, Z24.1-1936, is now available in printed form and may be obtained from the American Standards Association, 29 W. 39th Street, New York, at the price of 25 cents a copy. The work done by the committee in developing this standard will be productive of the best results only when the standard is used widely by all interests concerned. The ASA is doing everything possible to promote the use of the standard, but the cooperation of the individual member organizations is essential. To help secure the practical adoption of the standard, adequate reference should be made to it in reports and publications so that all concerned may realize the value of the standard.

The printed report on Sound Level meters, Z24.3, which was distributed some time ago, was well received by those concerned. No important suggestions for revision have arisen. It had developed, however, that there was some question as to how well meters of different manufacture were maintaining their relative calibration. Various manufacturers will exchange meters in order that comparative tests might be made on their calibration.

The report on microphones has been published in "Electrical Engineering" and in the Journal of the Acoustical Society. Only minor comments have been received. The National Bureau of Standards has been requested to act as the calibrating agency for acoustical apparatus. The director of that institution has already agreed to undertake the responsibility of doing the calibration work. Members of the committee have offered to cooperate with the National Bureau of Standards in every possible way in this matter. The users and makers of microphones may, therefore, look forward to the time when a national agency for microphone calibrations will be existing.

At the suggestion of Dr. Olson, chairman Technical Committee on Electro-acoustics, of the IRE, the ASA will set up a subcommittee to deal with the calibration of loudspeakers.

Variation of Permeability of Iron Cores With R.F. Signal Level

By J. E. Maynard, General Electric Company

It has doubtless been generally suspected by those concerned with the problems of the design of radio circuits, including cores of finely divided iron or other solid magnetic materials, that measurements of sufficient precision would reveal characteristics not unlike those found in iron when used at audio and power frequencies. That is, one might well expect the usual relationship between flux density and permeability as suggested by the usual shape of B-H curve and the usual relationship between power loss—equivalent resistance—and the excitation amplitude along with saturation effects where sufficiently precise measurements are made over a sufficiently wide range of conditions to bring out the characteristics of the material.

In the investigation here reported, however, only the relationship between the amplitude of the excitation and the permeability was of interest. More specifically, this work resulted from the fact that during the development of iron plug trimming for A. F. C. transformers, it was noted that an apparent shift in tuning took place in the circuits including the iron plugs at high signal levels. This observation called for a more careful determination of the nature and extent of the phenomenon as reported below.

The circuit shown in Figure 1 was set up to obtain data on this subject.

It will be noted that this includes a 6K7 along with the circuit L, C, including the iron plug, and the diode rectifier in conventional arrangements, with the addition of a microammeter in the diode circuit for the determination of the peak value of the output voltage.

The 6K7 was biased at –3 volts with 100 volts on the screen and 250 volts on the plate. The coil L, of 7/41 Litz and designed to accommodate the iron cores of one-half inch diameter was approximately one millihenry in inductance. The diode load resistor was a four-megohm unit and thus provided little loading of the circuit L, C, and consequently, little reduced the sharpness of resonance of the L, C, circuit as is required for highly precise recognition of the resonant frequency.

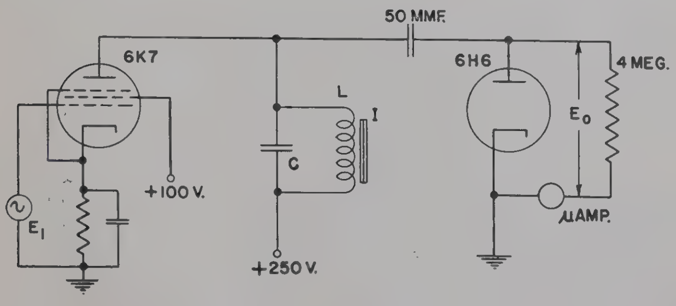

FIGURE 1

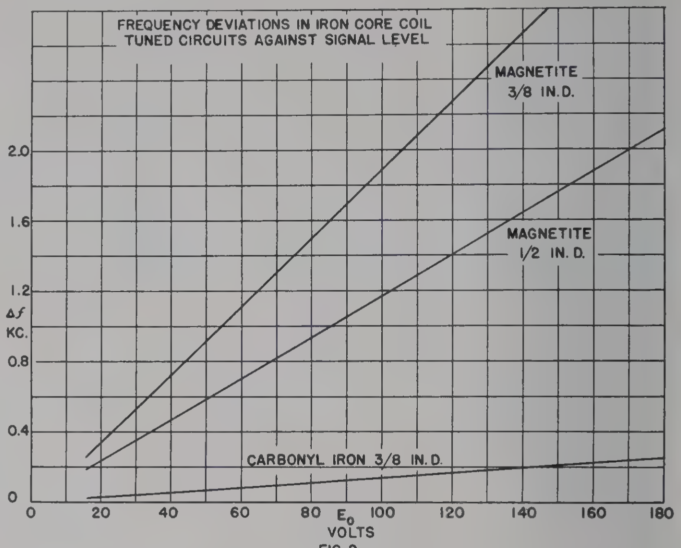

FIG. 2.

The input voltage, E, was supplied by a conventional type of signal generator the frequency calibration of which in conjunction with circuit resonance was such as to allow of the recognition of frequency changes of one hundred cycles with negligible error.

In making the measurements, the signal generator and the circuit, L, C, were tuned to 465 K.C. and the input voltage adjusted to give an output voltage of 7 volts as indicated on the diode peak voltmeter. The input voltage was then increased in steps to one-half volt.

At each increase in input voltage or signal level, the signal generator was retuned for maximum output voltage and the change in frequency (△f) from the original low level setting was noted. Data were obtained for several different types of iron cores and core materials by this means and are shown in the curves of Figure 2.

It will be noted that the data indicated linearity between frequency departure and output voltage within the accuracy of measurement. Several cores of each type were measured and found to depart less than ±10% from other similar cores. A few cores were measured at 175 kc and the frequency deviations were found to be approximately proportional to the resonant frequencies (175 kc and 465 kc) at the same signal levels.

It should be noted that the direct current through the coil was substantially independent of signal level through-

(Continued on Page 32)

Oscillator Stabilization

By C. E. Granqvist, Aga-Baltic Radio A. B.
Stockholm, Sweden

During fading of broadcast transmissions the signal received varies considerably in loudness. Attempts have been made to correct this by so called automatic volume control, i.e. control of the amplification in the receiving apparatus in a direction reverse to the variation of the signal strength owing to fading, so that at reduced intensity of the incoming signal the amplification will be greater and vice versa. According to the practice now generally adopted the automatic volume control is secured by using tubes with variable amplification, the amplification being regulated by a variable bias that varies according to the intensity of the incoming signal. By such means it is possible to obtain very good stabilization of the volume reproduced, but the arrangement has been found to have other disadvantages.

When the voltages applied to a tube are altered, a change also takes place in the slope and inner resistance of the tube. If this tube functions as an oscillator, the tube is connected to a frequency-determining circuit, the electric elements of which also include the transformed inner properties of the tube. If these properties now are altered, it is evident that the frequency of the frequency-determining circuit will also change. This entails, however, a displacement of all the interference frequencies that may possibly occur between the oscillator frequency and the signal frequency, thus in superheterodyne receivers for instance, a displacement of the intermediate frequency formed. This new displaced intermediate frequency is fed through a series of tuned circuits in a superheterodyne receiver, which, however, are tuned to the correct intermediate frequency and not to this incorrect one. The detuning of the intermediate frequency produces distortion.

In practice this detuning can be readily noticed. Some receivers produce very severe distortion, when tuned to stations on the short wave band, which are undergoing severe fading, though the volume is maintained fairly constant by the AVC system. At the moment when deterioration in the quality of the signal is noticeable, the signal strength has faded down to a comparatively low value, and the automatic volume control arrangement has taken effect, and as a consequence of this the characteristics of the oscillator tube have been altered causing a drift in frequency, and detuning of the IF frequency.

Other difficulties are also obtained in the short wave range. Sometimes it will be impossible to tune the receiver to the desired signal, because of oscillations or "oscillator flutter."

These oscillations are normally created because voltage changes in the output or AVC-system will change the frequency of the oscillator. The oscillations obtained will be sustained due to the fact that both second and AVC detector, particularly when the receiver is a little detuned, are sensitive to frequency modulated waves and feed new energy to the oscillator. The output of the detector, when it is fed with a frequency modulated signal, depends upon the signal strength, degree of detuning and receiver selectivity. The dotted curve in Fig. 1 shows the output of a diode detector, when fed with a frequency modulated signal.

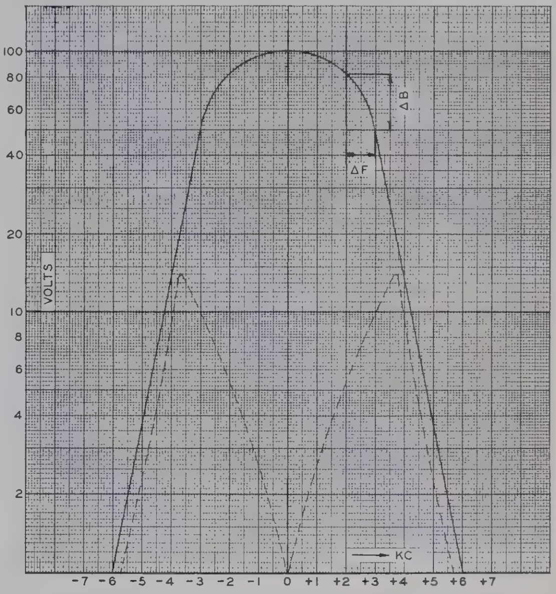

FIG. 1

In order to get a clearer view of these oscillation phenomena we divide them into three groups.

1. Microphonics.

Vibrations from the speaker will set some parts of the oscillator circuit into vibration and cause frequency modulation.

2. AVC-flutter.

The frequency in a combined modulator-oscillator is dependent on the AVC voltage. Therefore frequency modulation will occur, when the AVC voltage is varying.

3. Anode-flutter.

Changes in the B-supply voltage will change the oscillator frequency so that frequency modulation occurs.

MICROPHONICS

The method of avoiding this oscillation is to make, either the oscillator circuit insensitive to speaker vibrations or the detector to frequency modulated waves. The first thing can be done by using rubber bushings in

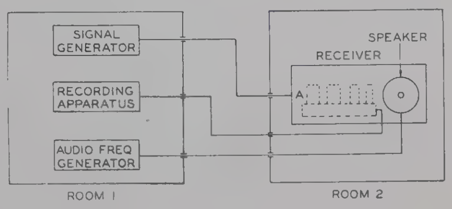

FIG. 2

mounting the speaker, chassis, tuning condenser etc. Detector sensitivity can be decreased by reducing the selectivity of the intermediate amplifier.

A very interesting method for studying microphonic phenomena is shown in Fig. 2. The output terminals of the receiver are connected to a recording apparatus and the speaker is connected to an audio frequency generator. The input terminals of the receiver are connected to a signal generator which is slightly detuned from the receiver frequency. The record will then show the frequency modulation caused by vibrations set up by the speaker. In order to avoid interaction between speaker and measuring instrument they are placed in different rooms. Sometimes it is advantageous to replace the AVC voltage with a battery and feed the output stage from a separate B-supply.

AVC-FLUTTER

A combined oscillator modulator tube is frequency-sensitive to changes in the AVC voltage. In order to avoid this frequency deviation it will be necessary to disconnect the AVC voltage from the tube, when the receiver is used in the short wave range. Fig. 3 shows how oscillations are built up through the AVC system. A change in the AVC voltage will change the frequency of the IF-signal and therefore cause a new change in the AVC voltage, so that sustained oscillation will be produced.

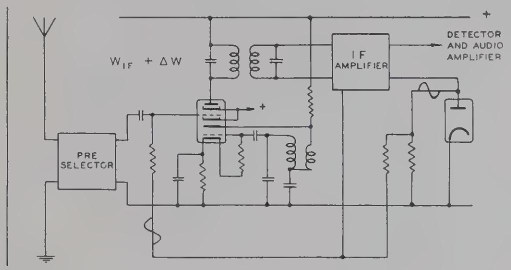

FIG. 3

One method of increasing the stability is to reduce the AVC detector sensitivity to frequency modulated signals by connecting this detector to an earlier stage in the receiver where the selectivity is lower. See fig. 4.

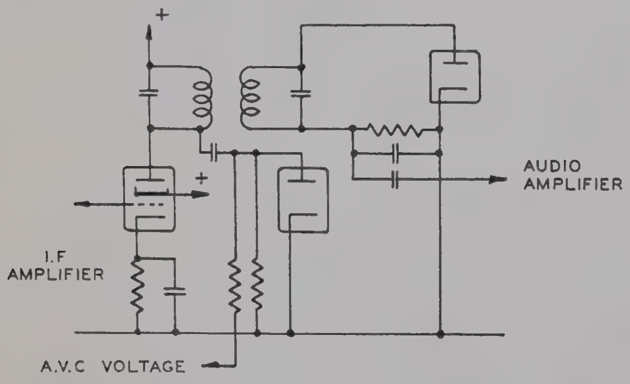

FIG. 4

The use of a separate oscillator is expensive and the disconnection of AVC voltage reduces the AVC action, so that another method is desired. In a later part of this paper an arrangement of the oscillator circuit will be described, which reduces the frequency drift of the oscillator.

ANODE-FLUTTER

The impedance of the B-supply is sufficiently high, particularly at low frequencies, to give variations in B-voltage with changes in the power stage anode current. As the oscillator frequency is dependent on B-voltage, frequency modulation will occur. See fig. 5. The impedance of the filter net work increases vary rapidly at low frequencies, so that the B-voltage will vary over wider limits at low frequencies. The way to decrease these variations is to increase the filter capacity or cut the frequency response of the audio amplifier in the lower register. Fig. 6 shows frequency response of feed back through audio amplifier and filter for two different audio response characteristics. It is therefore necessary to consider the desired audio frequency response and then design the filter net work.

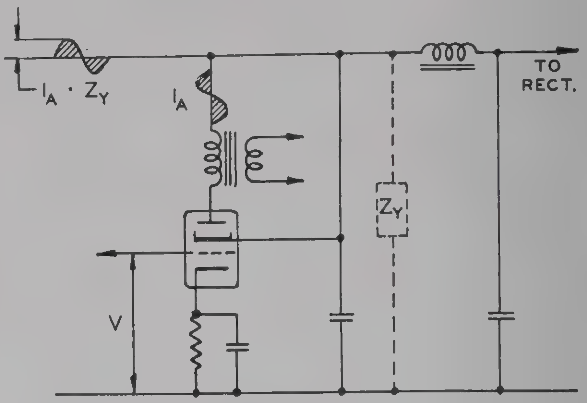

FIG. 5

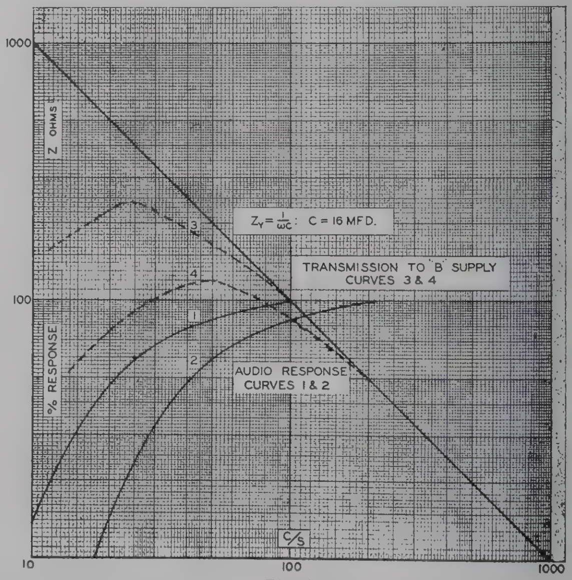

FIG. 6

An interesting trick is to design the resistor and condenser element in the audio amplifier, so that the feed back voltage is nearly 90° out of phase, when the amplitude has highest magnitude. This arrangement will increase the stability, because only the part of the voltage fed back which is in phase, will facilitate the oscillation.

The best arrangement is of course the use of an oscillator, whose frequency changes vary little with the B-voltage. Such an oscillator will be described in the next part of this paper.

STABILIZING OSCILLATOR FREQUENCY FOR CHANGES IN SUPPLY VOLTAGES

It is known that it is possible to cause an electronic tube to work as a variable condenser or inductance. The capacity of the condenser or the inductance of the inductance element thus formed is varied by varying the slope of the electronic tube. This may be effected for instance through alteration of the bias delivered to the grid. Fig. 7 shows such an arrangement. The impedance between the terminals 1 and 2, called Z, is obtained from the following formula:

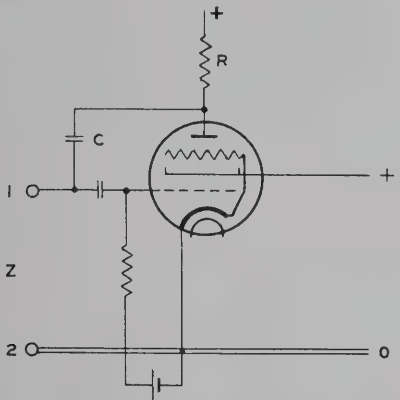

FIG 7

$$Z=\frac{1}{pC}\cdot\frac{1}{1+SR}+\frac{R}{1+SR}\ldots\ldots\ldots\ldots/1/$$

in which

Z is the impedance between the terminals 1 and 2.
p is the Heaviside operator ($j\omega$).
C is the capacity of the condenser.
S is the slope of the electronic tube (mutual conductance).
R is the resistance of the resistor in the anode circuit.

It is evident that the eff. capacity included in the impedance Z may be written as $C_{eff}=(1+SR)\ldots\ldots/2/$

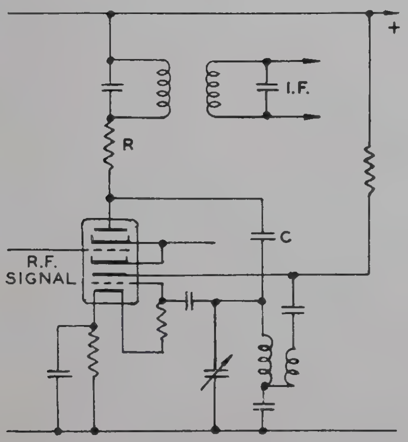

FIG. 8

It is obvious that it is possible to combine such a "capacity tube" with a normal oscillator in such a way that the "capacitive tube" will compensate for the frequency drift. The upper part of a combined oscillator-modulator tube can be used as such a "capacity tube," see fig. 8. The principle of this arrangement can easily be explained as follows. Suppose that the negative bias on grid No. 4 is increased. In consequence thereof the plate resistance of the triode part is decreased and therefore the oscillator frequency will try to increase. But the capacity formed by the upper part of the tube decreases at the same time, so that the frequency drift will be reduced.

Fig. 9 shows drift measurements made upon this arrangement.

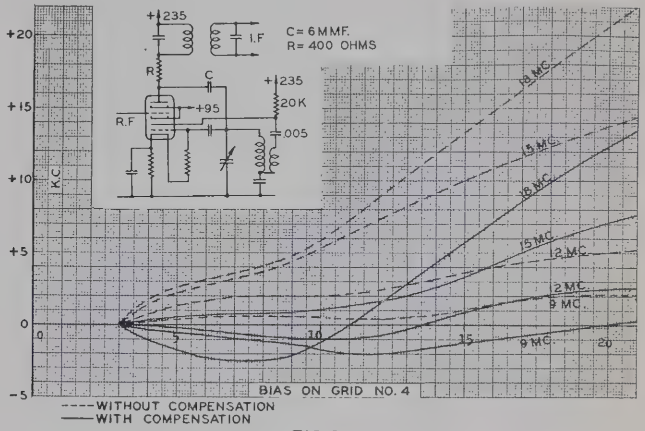

FIG. 9

It perhaps appears curious that the eff. capacity of the "capacity tube" will increase, when the bias on grid No. 4 is increased, but this is due to the fact that the phase relation between grid No. 1 and anode will change because the phase on the oscillator anode also will change with the inner resistance of the oscillator anode.

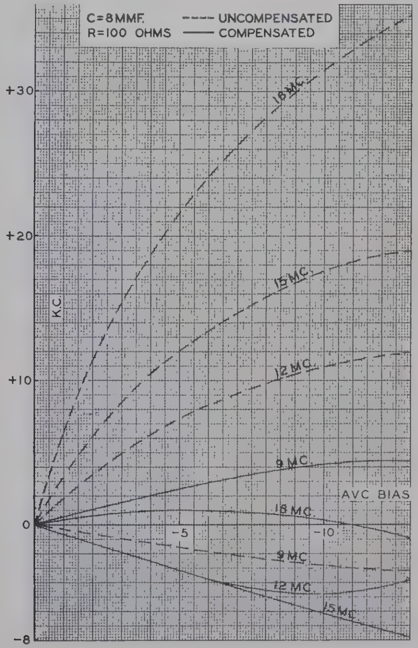

FIG. 10

The condenser element C can of course be connected to other parts in the oscillator circuit, for instance, to the oscillator anode. Fig. 10 shows measurements made with this circuit.

It is also possible to stabilize the frequency for changes in the B-voltage. Fig. 11 shows measurements of frequency deviation as function of B-supply voltage.

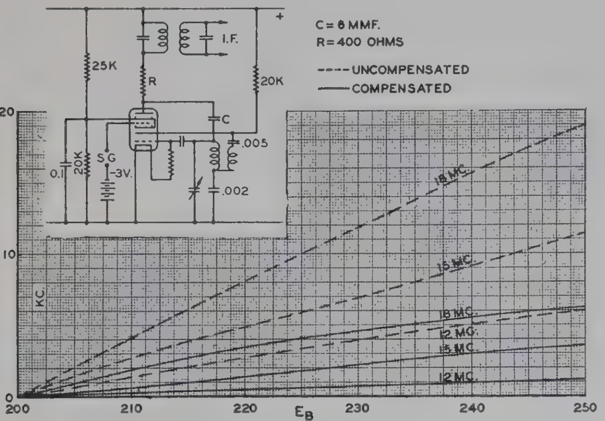

FIG.11

In order to make a mathematical solution of the mode of operation of the "capacity tube" it is necessary to know how the potential on the different grids changes the anode current.

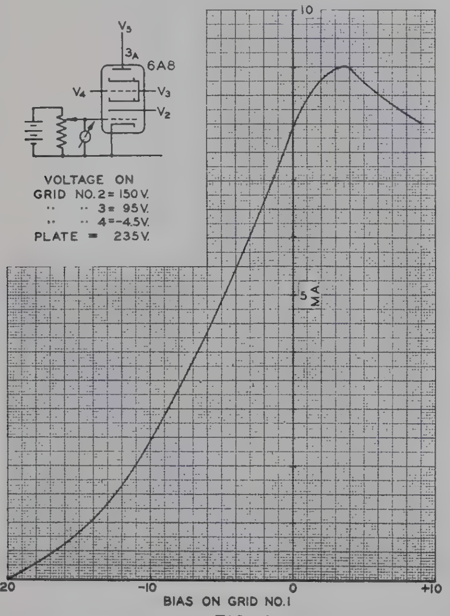

FIG.12

Figs. 12 and 13 show how the anode current will change with the voltage on grid No. 1 and 2, when normal potentials are applied to the other electrodes. From these curves it seems to be a good approximation to suppose that the anode current is dependent only upon the voltage on grid No. 1.

When the oscillator is working, the anode current will be of the same frequency as the oscillator and its magnitude will be determined by the voltage on grid No. 4.

Fig. 14 shows the relation between the H. F. anode current, and the potential on grid No. 4.

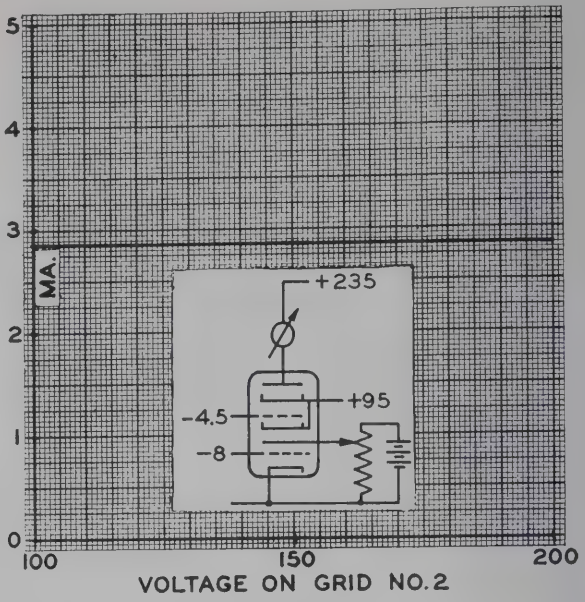

FIG.13

If we suppose that the anode current can be written as:

$$I_5 = -S \cdot V_I \quad ..../3/$$

it is easy to calculate the frequency correction with the voltage changes on grid No. 4.

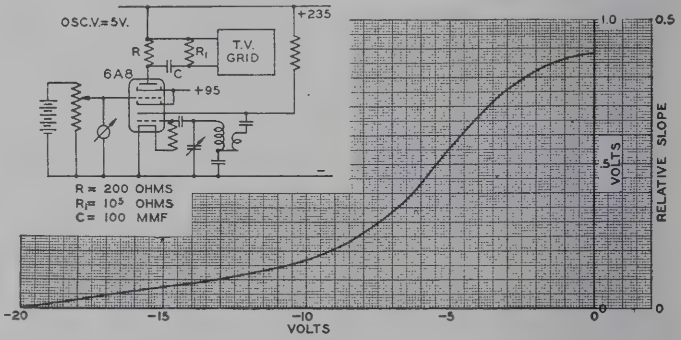

FIG. 14

This is done by calculating the change in reactance of the coil system assuming that the tuning condenser is disconnected. The reactance of the coil system, if we neglect the influence of the plate reaction coil, and assume the correction condenser to be connected to grid No. 1, will then be

$$Z = \frac{pL}{1 + pL \cdot \dfrac{1 + SZ_I}{\dfrac{1}{pC} + Z_I}} \quad ..../4/$$

Fig. 15 shows the equivalent circuit where

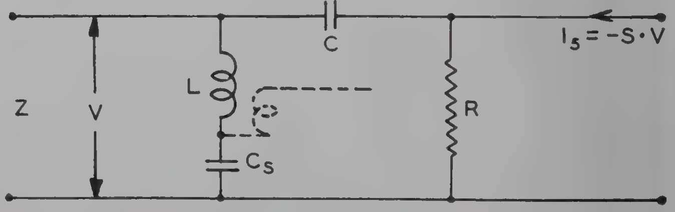

FIG. 15

$$Z_1 = \frac{R}{1+pC_1R} \;;\; pL = pL_1 + \frac{1}{pC_s}$$

L_1 = inductance of tuning coil
C_s = capacity of series condenser
C_1 = anode capacity of the tube
C = coupling capacity
R = resistance of resistor in the anode circuit.

The formula /4/ can also be written as

$$Z = \frac{pL}{1 + \dfrac{pL}{\dfrac{1}{pc}+Z_1} + \dfrac{SZ_1}{\dfrac{1}{pc}+Z_1}\,pL} \;\ldots\ldots\ldots/5/$$

The only part of this expression which is dependent on S is

$$\frac{S \cdot Z_1}{\dfrac{1}{pc}+Z_1}\,pL \;\ldots\ldots\ldots\ldots\ldots\ldots/5a/$$

A change in frequency is given by a change of the real part of the denominator. As the other parts of the denominator are small compared with unity, the frequency drift can be written as

$$\triangle\omega = \frac{1}{2}\,\omega^3 \cdot LC \cdot \frac{SR}{1 + \left[\omega CR(1 + \frac{c_1)}{c}\right]^2} \ldots/6/$$

Maximum frequency deviation is obtained when

$$R \cdot (c + c_1) = 1$$

If we introduce this quantity into the formula we will get

$$\triangle\omega_{\max} = \frac{1}{2}\omega^2 \cdot \frac{1}{V^2} \cdot L \cdot S \cdot \frac{c}{c+c_1} \ldots\ldots/7/$$

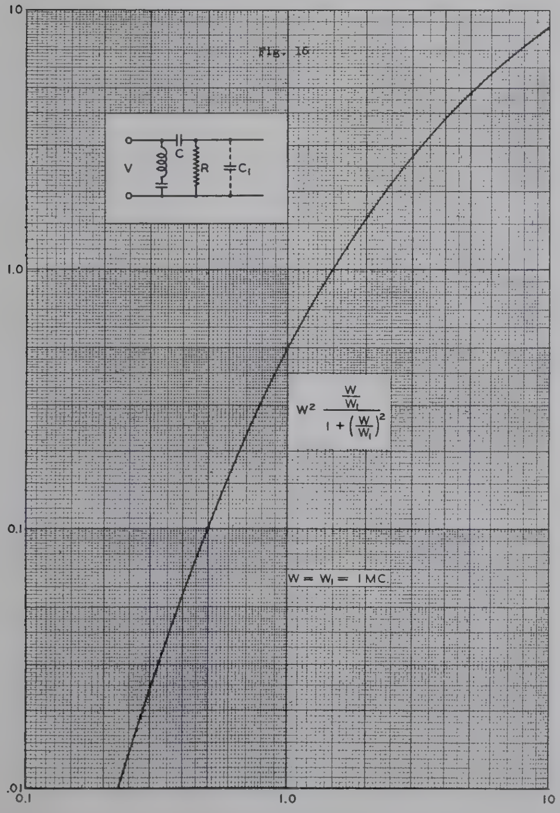

FIG. 16

Fig. 16 shows the frequency deviation at different frequencies compared with the frequency where the maximum condition is obtained.

The condenser C can of course be connected to another point in the oscillator circuit, for instance to the series condenser.

Similar equations are easily computed; so that the deviation for a given change in S will in this case be

$$\triangle\omega = -\frac{1}{2}\,\omega\,\frac{SR\left(\frac{C_s}{c}+1\right)}{\left(\frac{C_s}{c}+1\right)^2 + (C_sR)^2} \ldots\ldots/8/$$

Maximum frequency deviation is here obtained for

$$C_s R = \frac{C_s}{c} + 1$$

so that

$$\triangle\omega_{\max} = -\frac{1}{2}\,\omega\,\frac{S \quad R}{V^2\left(\frac{C_s}{c}+1\right)} \ldots\ldots/9/$$

Fig. 17 shows the frequency drift for different frequencies compared with the frequency where the maximum condition is obtained.

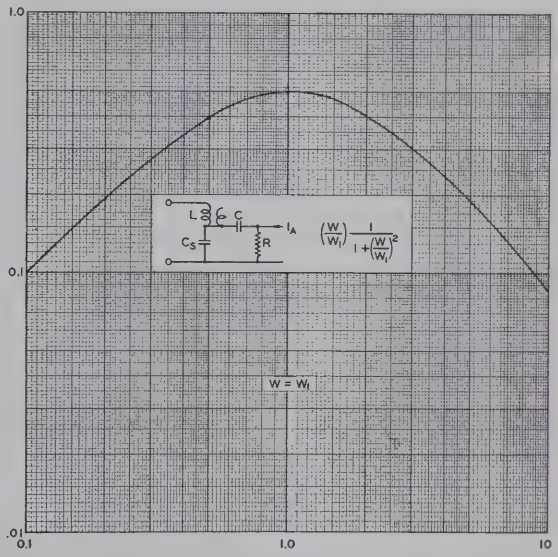

FIG. 17

The above mentioned formulas are quite true in the long and broadcast band, but are not true in the short wave band. This depends on the fact that the frequency drift is very sensitive to changes of the phase difference between grid No. 1 and the anode current. At higher frequencies the impedance of the oscillator anode capacity is not small compared with the internal resistance of the tube. A change in the resistance will therefore cause a change in the phase angle. The frequency sensitivity for a change of the above-mentioned phase angle can be calculated by writing

$$S = S_o \quad e^{j\mu}$$

where

j is the complex operator and
μ is the phase angle between grid No. 1 and anode.

(Continued on Page 30)

An Introspection of Engineering Organization

By E. F. Carter, Hygrade Sylvania Corporation

We of the radio profession should be particularly interested in "The Human Side of Engineering" because radio has played such a very important part in social progress even though it is still in its infancy. It cannot help but continue to aid in the advancement of understanding between all peoples and the general improvement of social conditions. It is only necessary to let one's imagination run its course to think of the number of good things that radio has and is contributing to humanity.

It is generally being recognized that a strictly military organization is no longer applicable for work involving highly trained men of varying temperaments, ideals, and attitudes. By a "strictly military organization" we mean one in which the will or orders of the superior officers must be carried out to the letter by those who are subordinate to him and we usually think of an industrial organization operated in this manner as one in which the executives attempt to get results by continually driving rather than leading its personnel. Unfortunately for those who have sought and are seeking to make this type of an organization produce, intelligent human beings do not react well to such treatment. In fact we are coming more and more to the realization that all human beings, whether they are mere children or highly educated specialists can and will produce much better results when they are dealt with in accordance with certain well established principles, than when ordered to do another's will whether they like or not.

Modern psychology has done much to give us the proper appreciation for the application of those principles which were summed up 2000 years ago in the Golden Rule. Since we are all human and since we all react more or less the same way to the assertion of authority on the part of others it becomes almost obvious that the way to determine how one of our associates is apt to react under certain conditions is to first consider how we would react under the same circumstances. If we can do this sincerely and then treat the other fellow just as we would like to be treated we have learned the art of dealing with people and as a result we will give cooperation and receive cooperation in return.

Now let us for a moment consider the value of cooperation. It is only natural that in any organization whether it be large or small there will be differences in opinion. Too often these differences are magnified to such an extent that jealousies, rivalries, and ill feelings develop with the result that cooperation is entirely lost and it is impossible to do our work efficiently. This results in poor morale and general dissatisfaction which usually ruins a complete organization. Sometimes this lack of cooperation may appear between the engineering and the sales departments, sometime it is between the engineering and manufacturing departments, and at other times it is within a single group. The sad part about it is that it results more often from defects in personality than it does from lack of technical training or skill. In the various stages of our education we have learned much about sciences, about languages, about history, etc., but many of us developed our personalities when we were children and although we have since had an opportunity to add greatly to our scientific and academic knowledge we have had very little instruction in the art of living and getting along with people. Therefore unless we have made it a point to experiment with and carefully observe the reactions of others we will find certain people with whom we just cannot get along, and nine times out of ten we will blame the trouble upon the other fellow rather than upon ourselves. Now the difficulty is that the other fellow probably has the same deficiencies himself and he in turn does not realize his contribution to the grudge or feud or whatnot. Each of us could well spend more time in introspection, first of himself as an individual and then of his organization to determine whether or not the facts just outlined apply; then having, by some effort and practice overcome these deficiencies, apply himself to making the organization of which he is a part an efficient and successful one.

For the younger engineers and those doing specific work the adjustment should not be quite as difficult as for those having greater responsibility because of the limited number of contacts and of diverse opinions connected with his specific undertaking. The man in a position of greater responsibility in most instances has achieved his position by having demonstrated his ability to get results, though in some cases he is not able to go farther because of his lack of appreciation of fundamental factors dealing with human relations.

Let us now look into some of the personal hurdles that are often hard to take. It is only natural that an engineer should have a certain degree of pride. He has spent considerable time and effort in securing his training and if he had no pride whatsoever he would not be very much of an asset. On the other hand there are many costly mistakes made because an engineer's pride is so great he is not able to recognize a good suggestion made by someone else, with the result that he laboriously accomplishes something that is less satisfactory but which he subconsciously justifies because the ideas were all his own. You no doubt, have known many cases of this sort and have heard comments by certain men to the effect, "I don't see why so-and-so gets along so well when he scarcely ever has an original idea and I contribute so much." To my mind it is more important to be able to recognize and utilize good suggestions made by another, giving credit of course to the originator of the idea, than it is to have all of the ideas oneself. Everyone cannot be a genius, but each individual can cultivate good judgment and appreciation for the other fellow's work. Furthermore, the ability to recognize a good contribution on the part of another fellow shows strength of character.

Another hurdle we have to pass is just plain stubbornness. We set our minds on doing a thing in a certain way, even though the factory, the sales department, or the customer may prefer some other equally good approach. We may recognize that the other method is just as satisfactory, but with the feeling that we must save our face we stubbornly oppose a compromise. This like other things works in both directions and though it is important that one takes a firm stand when a matter of high principle is involved, the ability to compromise builds, rather than destroys, prestige.

It is hard to take criticism, especially if such criticism is unjust. Complaints are often received from a customer which obviously resulted from mis-use of the product involved. One of the best ways of losing such a customer is to become angry and accuse him more severely than he deserves. The mis-use is in most cases due to inadequate exchange of information. A good engineering organization must place a great deal of emphasis on customer contacts. It is important that the men chosen for handling these contacts have personalities that demand respect. It is also important that they have a keen insight into the customer's problems so as to avoid any possibility of misunderstandings.

In this connection a few words should be said about the importance of maintaining a high standard of quality of product. It is obvious that the amount of criticism, just or unjust, that is received will depend to a great extent upon the standards of quality that are set for a good product. Occassionaly the temptation to relax high standards of product quality develops; especially then it should be remembered how otherwise successful organizations have paved their way to failure with false ideas that costs could be lowered by a sacrifice of quality. Paradoxical as it may seem, it has been proven time and again that rigid standards of quality can and actually do result in lower cost because they require the elimination of conditions that should not have existed in the first place. Since engineering departments are responsible for quality control, a thorough understanding of the application of the product is essential to the setting of proper limits and tolerances. Technical information alone however cannot take the place of the proper attitude toward the ultimate consumer. Here, again, the criterion should be that of placing oneself in the position of the ultimate consumer and the standards should be set accordingly.

In any organization personal deficiencies in individuals may be reflected by the whole group, especially if the individual in question holds a responsible position. Critical statements concerning other organization men should be avoided since a statement concerning a fault in one who is otherwise highly respected may so seriously lower his prestige in the minds of other members of the organization as to result in a loss of confidence in him and in a general lowering in organization efficiency. Just as it is important to maintain close contacts with the customer and to develop a sympathetic appreciation of his problems, so is it essential for the engineering organization to understand and appreciate the problems of the manufacturing and sales organizations within a given company. Typical of the lack of this mutual understanding is the statement made at one company which I have in mind to the effect that, "If the Sales Department could just do the engineering and the Engineering Department could do the selling, everything would be all right." The same thing has doubtless been said at times about engineering and manufacturing, manufacturing and sales, etc., since it is always easier to see the other fellow's faults than to see our own. An appreciation of the nature and magnitude of his problems is the first essential to the development of the cooperative attitude requisite to organizational success.

This should not be misconstrued however to mean that we should attempt to run the other fellow's job because in doing that we immediately disclose our lack of confidence in his ability and we lose, rather than gain, in cooperation. This applies not only to men who are of equal assigned responsibility but to those of subordinate responsibility as well.

A man is not himself capable of assuming responsibility unless he can delegate responsibility to his subordinates while simultaneously establishing the conviction that he has confidence in their ability to discharge that responsibility. Indeed, a good executive is primarily one who can build confidence in the minds of his subordinates and thus inspire them to do more than they realized was possible, he, himself, giving detailed assistance only when needed.

As an organization becomes larger and larger it becomes increasingly difficult to coordinate the activities within a department especially if physical separation of its parts is involved. To a large extent this is also due to the lack of development of mutual understanding as a result of inadequate contact. It is still more difficult to coordinate the work if there is a duplication of effort by groups that are isolated by distance. A typical example of that developed in a company which had one engineering group in New York and another at its factory in the midwest. The factory manager, unfortunately, proved to be an excellent salesman as far as his superiors were concerned and as a result the production designs were those secretly developed by the engineers at the factory sponsored by the production manager. The results were as expected—the company liquidated its business in the early Fall.

In conclusion, emphasis is again directed toward the importance of internal cooperation and upon a sincere effort to fully understand and appreciate the problems of others, bearing the thought in mind that we are all human and that the other fellow wants to be treated the same as we, personally, do.

The Practical Application of Vibrator "B" Power

By GEORGE A. GERBER, Zenith Radio Corp.

The vibrator type of "B" power supply has unquestionably been one of the major developments in the history of radio, and has made possible present compact, lightweight farm, boat, trailer, automobile and other low voltage, D.C., operated receivers, possessed of performance rivaling many alternating current operated home receivers.

It is unnecessary to here review the history of this device, or to enumerate the many operating inconveniences of which it disposed at one bold stroke.

However, it brought with it into the field of radio receiver design a multitude of engineering headaches which will long be remembered by those who have been associated with its wedding to the radio receiver.

Since the day when the idea of using a vibrating pole changer in conjunction with an alternating current step up transformer and a high voltage rectifier was accepted in engineering circles as a practical means of obtaining "B" power from a voltage low D.C. source, engineers have bent every effort toward improvement of the design of the components and circuits associated with its use.

Of these the two major problems and those with which this paper deals are "hum" or "hash" disturbances as generated by a typical vibrator "B" supply arrangement and circuit arrangements that have been found in practice to provide a satisfactory means of reducing these disturbances to an acceptable minimum.

Much has been written dealing with the origin, nature and measurement of these disturbances, but the many theoretical discussions thus far published have presented little information useful in practical circuit design and application.

Two types of vibrators are most commonly used, the so called synchronous and non-synchronous types, differing, mainly, in that the synchronous type utilizes an extra set of contacts to perform the function of rectification of the stepped up secondary voltage, while the non-synchronous type uses the primary contacts only, a tube being generally used for rectification.

Because of the extra secondary contacts of the synchronous type, it is usually somewhat more difficult to adequately suppress the radio frequency "hash" with this type of vibrator, and the "static shield" commonly used between primary and secondary windings of the power transformer is considerably less effective, due to some random sparking which occurs at the secondary contacts. When due precautions have been taken elsewhere in design, the merit of the static shield is questionable and it has, in certain instances, been found economically sound to omit this item from the power transformer cost.

Measurements made on a large number of vibrator circuit designs indicate the overall efficiency of the synchronous type to be approximately 70%; and for the non-synchronous type approximately 60% not including the power taken by the rectifier tube heater.

Factors accounting for this difference are rectifier drop in the case of non-synchronous operation and the lesser primary contact loss in the synchronous type due to the fact that the primary points are usually adjusted to make and break under no load.

Vibrator reed frequencies are usually established by the manufacturers of this component and are chosen by them after having conducted a multitude of experiments and life tests, and have been fairly well established as 100 cycles per second for Household Receivers, 100 to 110 cycles per second for Automotive Receivers, and in the range of 70 to 75 cycles per second for heavy duty inverter service.

The tolerances on reed frequency in production are usually 5% or less.

The usual precautions must be observed against permitting speaker or cabinet to resonate at the vibrator frequency and thus producing an abnormally high hum level.

For satisfactory operation under extreme conditions which may be encountered in the field, the circuit breakdown safety factor should be such as to safely permit operation at a supply voltage of 33% in excess of optimum, and the excitation system of the vibrator should start and operate the vibrator satisfactorily at a supply voltage of 33% below optimum.

The wave form of a vibrator circuit designed and adjusted for maximum efficiency and long vibrator life, is almost certain to show a minimum of hum and radio frequency "hash." In the accomplishment of this, a cathode-ray oscillograph is almost indispensible.

Generally it is found impractical to mount the vibrator in a so-called floating socket to reduce transmission of mechanical vibration from the vibrator to chassis, and cabinet. The usual method is a rigid mounting with good electrical contact between the vibrator outer can and the chassis, and the free suspension of the vibrator within the can in a sponge rubber cushion of sufficient thickness that the whole attenuates directly radiated acoustic noises to an unobjectionable level, and permit the vibrator to dissipate the greater amount of its own mechanical vibration within itself.

A certain amount of mechanical vibration may be tolerated in household receivers, if the chassis, proper, is floated on rubber and precautions are taken to prevent any part of the chassis assembly from touching the cabinet.

A difficult hum problem commonly encountered in short wave receiver design where audio gains of 1000 and higher are desirable to provide the necessary power sensitivity to insure satisfactory reception of weak signals, is that of "pickup" by the diode circuit and first audio grid leads of power supply harmonic voltages of high order thus producing a singing type of hum response. Providing the volume control with a static shield between the off-on switch and the control element, bonding this shield and the control shell, if it be of metal, to the chassis base, and the careful routing or shielding of the live

"A" line from audio input circuits are effective remedial measures.

Occasionally it has been found necessary to provide shielding of associated audio input leads and separation or shielding of audio input components from the heater wiring and live "A" lead.

Vibrator "B" supply circuits are usually used in receiver circuits which of necessity must possess great sensitivity, and it therefore becomes a major problem to suppress random radio frequency "hash" noises.

In certain designs where available chassis space will permit, an adaptation of the "screened room" to a "power box" design has proven extremely effective.

This type of design was first adopted for use with a farm receiver in which provision was made for the unit to be sold originally for A, B, and C battery operation, and later could be converted to operation entirely from a six-volt storage battery. This arrangement made necessary the provision of a power pack which contained the vibrator, transformer and associated parts.

Figure one is a Pre-Assembly view of such a power box where it will be seen that the power transformer, synchronous vibrator, filter choke and electrolytic condensers are all mounted on a small sub-base, the buffer condensers and hash filters being arranged for short leads, etc., on the underside of this base while this entire assembly is constructed to mount inside of a steel box.

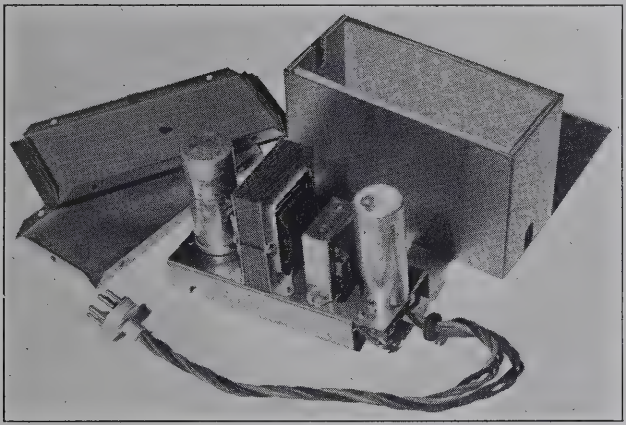

Fig. 1

Figure two shows the basic circuits as used. It will be seen that a common ground on the underside of the sub-base is used for all "hash" conducting circuits to prevent as far as possible stray circulating currents in the sub-base. A ground lead is carried from this point to the receiver chassis. All other circuits leaving the box are filtered to prevent hash from leaving the box.

During development of this unit, a great deal of "hash" coupling existed even after all of the leads coming from the unit had been throughly filtered. Investigation indicated that this coupling was caused by high circulating currents existing in the shield box itself. Fortunately, the cure was simple. The sub-base was insulated from the shield box and then bonded to the shield box at one point. This treatment removed the high circulating currents from the box and a careful check for "hash" coupling, showed it to be entirely absent.

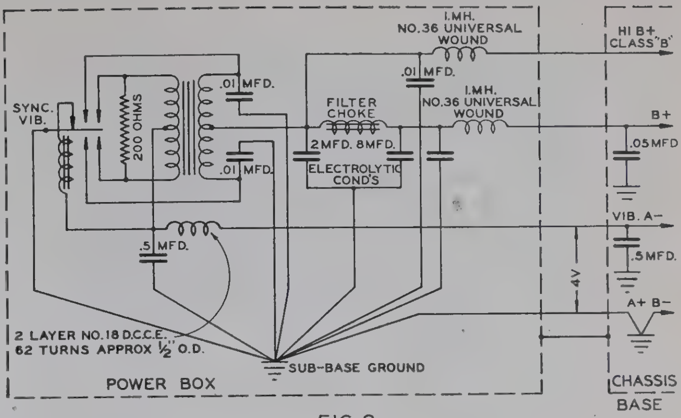

FIG. 2

BASIC CIRCUIT DIAGRAM, ZENITH ECONOMY PACK. (TYPICAL VALUES SHOWN.)

Later work on other designs where the vibrator unit and associated parts were placed on the receiver chassis itself has proven this treatment to be sound. A box designed in this manner can usually be applied to the receiver circuit and no intricate chassis bonding is required.

It has been observed in previous designs of vibrator type receivers, that it was necessary to do a large amount of bonding in order to keep hash at a low level and that in certain cases these bonds were required at locations well away from the vibrator unit itself. The explanation for this appeared to be circulating currents existing throughout the chassis base, and that when a bond was placed judiciously, cancellation would occur.

Quite a number of vibrator sets have been designed using the procedure outlined above, and it has been entirely unnecessary to use bonding of any nature. Furthermore, it was found that these units will run in production uniformly low in hash level, which, incidentally, had not been true in previous designs.

It is well to maintain the usual close tolerance on vibrator reed frequency and buffer condenser capacity in order to insure long vibrator life and a minimum of hum and radio frequency "hash".

A buffer value slightly large for a new vibrator usually provides somewhat longer vibrator life, but causes a new vibrator to generate a somewhat greater amount of radio frequency hash than if the buffer were optimum, or somewhat less than that. "Center tapping" the buffer condenser and grounding this point has proven to be very effective in "tying down" disturbance carrying circuits with a resulting material reduction of "hash" coupling from these circuits.

It has been found that when using the "power box" design, some departure from the usual hard and fast rules may be permitted. "Hash" filter condensers returns may be made at points on the sub-base other than the central "common ground" point without giving trouble and in a large number of designs it has been unnecessary to use the more costly braid lead or other types of "low reactance" condensers at any point in the circuit.

Figure three shows a pre-assembly view of a more recent design of a power box where the power transformer, non-synchronous vibrator and tube rectifier with their directly associated components are assembled on the sub-

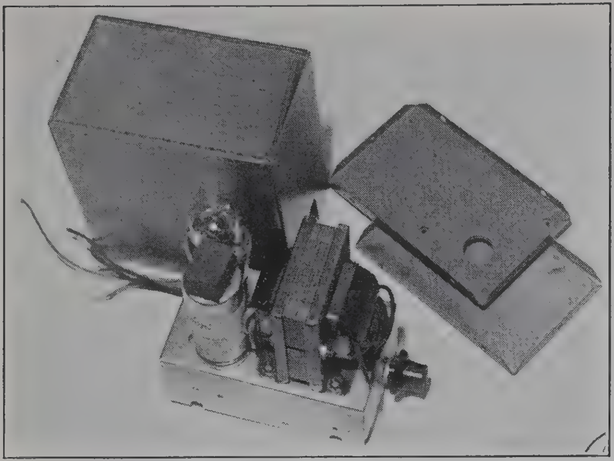

Fig. 3

base, the filter choke and electrolytic condenser being mounted on the receiver chassis base.

Figure four shows the basic schematic of this box.

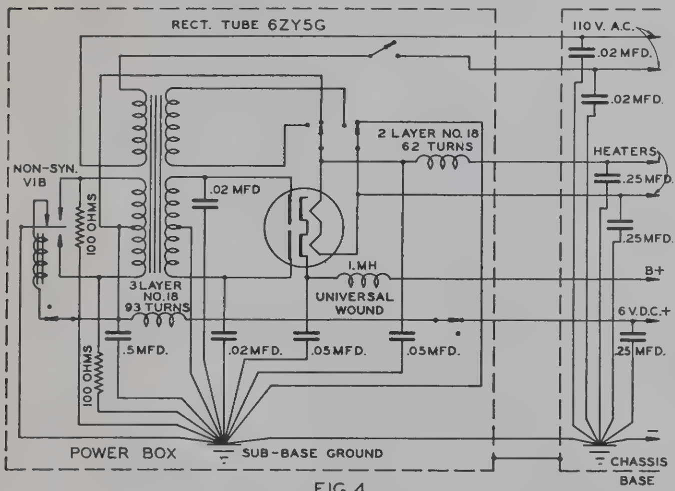

FIG. 4
BASIC CIRCUIT DIAGRAM. ZENITH 6V. D.C.-110V. A.C. POWER BOX
(TYPICAL VALUES SHOWN)

It has been found advisable to follow the layout arrangement in figure five closely with the chassis bypasses, although it is usually unnecessary to use a strictly "common ground point" for them. Chassis using this arrangement, invariably exhibit none of the vexing "best spot grounds," or circulating current cancellations, and the addition of capacity to the receiver circuit when necessary for other reasons rarely if ever causes "hash" to appear.

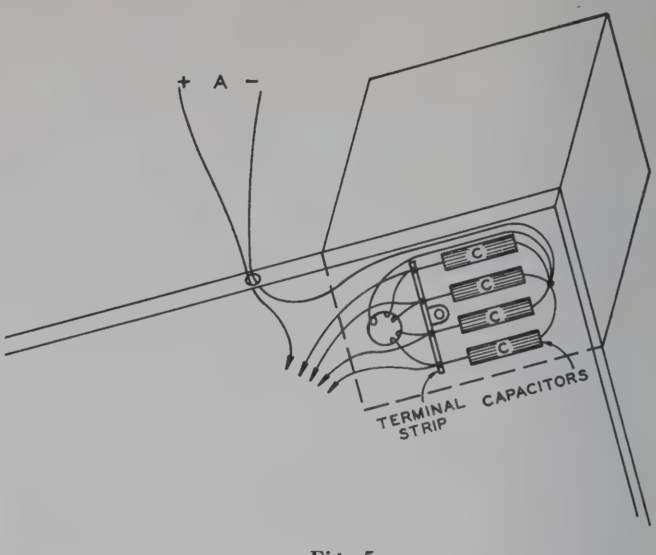

Fig. 5

In conclusion, it may be well to sum up the advantages to be realized by the use of the power box previously described as follows:

The reduction of chassis base currents to a practically undetectable quantity; a consequent similar reduction of coupling from vibrator circuit, components, and shields; the elimination of intricate and questionable chassis base and component bonding usually required on open base layouts; an additional attenuation of directly radiated mechanical noises from the vibrator; a substantially trouble free uniformity of production and the reduction of vibrator circuit design to a predictable basis as consistent as other phases of receiver circuit design.

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Use of Negative Regeneration in Radio Receivers

By C. B. FISHER, Northern Electric Company, Limited

Summary

The relations in an amplifier with feedback are derived, using both the direct analysis, and the equivalent amplifier theorem due to Baggally. The previously unpublished factor of phase-shift stability is derived. This analysis is carried out only for unilateral amplifier and feedback circuits. A discussion of nomenclature and symbolism is given.

The application of negative regeneration to a radio receiver is discussed under the following headings:

AUDIO AMPLIFIER:—For reduction of output impedance, constancy of gain, reduction of noise and distortion.

I. F. AMPLIFIER:—For control of selectivity.

ANTENNA CIRCUIT:—For reduction in emission noise.

LOUDSPEAKER:—For reduction of the electro-mechanical impedance between the amplifier and the diaphragm.

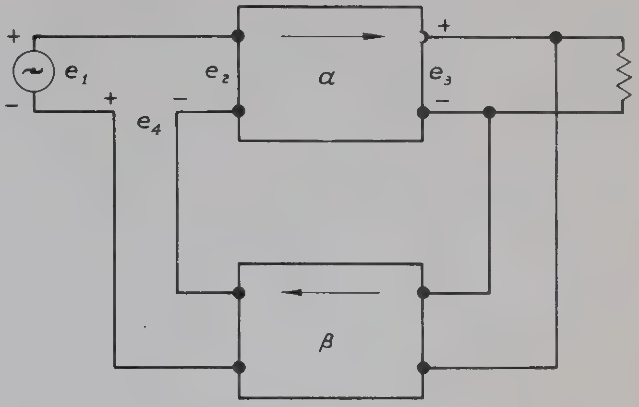
Introduction

Circuits involving negative regeneration to secure beneficial results have been in use for many years. As early as 1925 the application of negative regeneration to audio amplifiers appears to have been well understood[1], [2]. More recently a great deal of study has been given to the subject, and a number of papers have been published in the last 6 years. A fairly complete list of these is given at the end of this paper.

An explanation is perhaps in order, before the present writer adds one more paper to those already printed. A paper by Black [10] is perhaps the only one yet published with any pretense to completeness. Even this paper does not derive the important relation of stability against variation in phase shift. Other papers have suffered from painful errors, incompleteness, and variations in nomenclature and symbolism. It is hoped that the present discussion will be readily assimilated and complete enough for the purposes of the average circuit engineer. In no sense is the discussion considered exhaustive, and for more material the reader is referred to the papers in the bibliography. It should be realized, however, that important fields of the topic are not as yet covered by published material.

Theoretical Analysis

The mathematical theory necessary for a useful knowledge of negative regeneration is surprisingly simple. It is somewhat more difficult to express the results in physical terms. Since the facility with which an engineer utilizes theoretical reasoning is in direct proportion to his physical grasp of the results, it is desirable to express results in a concrete manner. Accordingly, we will use two separate methods of approach. The first, used by Black[10], is straightforward, but the results are not reducible to the simplest terms. The second method, originated probably by Baggally[6], [13], expresses the results more simply.



$$e_3 = \alpha e_2$$
$$e_4 = \beta e_3$$
$$e_2 = e_1 + e_4$$

Fig. 1

Method of Vector Field

Consider the diagram of Fig. 1, which shows an amplifier, connected to a load. The complete amplifier performance with this load is expressed by the equation:

$$e_3 = \propto e_2 \ldots\ldots (1)$$

where e_2 is the voltage across the input terminals, and e_3 is the voltage across the load. The quantity $\propto$ is not restricted to real numbers, and may have any finite value. $\propto$ is **not** the equivalent amplification factor of the amplifier, as may be shown by noting that its value depends on the load impedance. $\propto$ is assumed to be independent of time and of e_2. It is also assumed that the amplifier is unilateral. That is to say, if the feedback circuit β and the source e_1 be disconnected, and a voltage set up across the output terminals, no resultant voltage appears across the input terminals. Practical amplifiers usually satisfy this condition, and even if the condition is not satisfied, most of the usual results of negative regeneration can be observed, although the analysis is more involved than that given below.

A feedback network is connected between the input and output circuits, and is so arranged that a voltage derived from the output terminals appears at the input terminals. The quantity β is defined by the following equation:

$$e_4 = \beta e_3 \ldots\ldots (2)$$

As with $\propto$, β need not be real and may have any finite value or zero. The analysis will be carried through on the assumption that the β network is also unilateral.

The assumed phase relations of e_1, e_2, e_3 and e_4 are fixed by the following relation, which holds when $\propto$ and β are positive real numbers:

$$e_2 = e_1 + e_4 \ldots\ldots (3)$$

Instantaneous voltage polarities are shown in Fig. 1 for this condition.

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[1] Numbers refer to Bibliography.

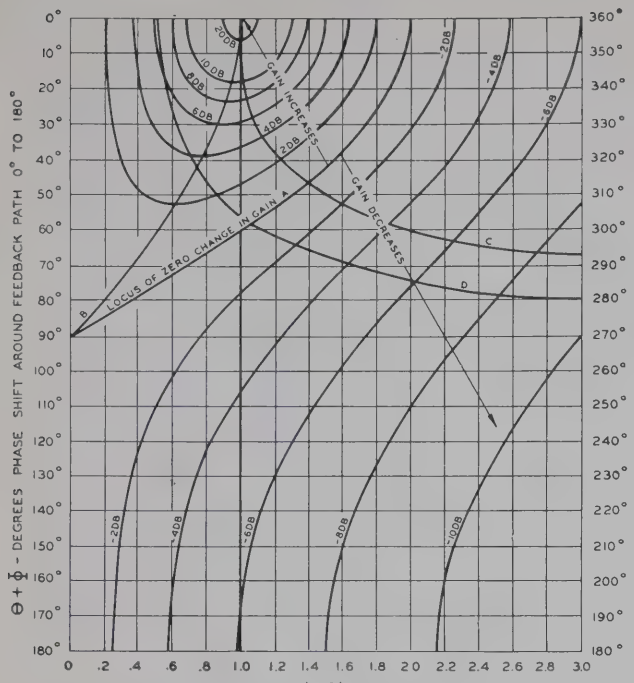

Fig. 2

The introduction of feedback causes changes in the gain, stability, non-linearity and frequency response of the amplifier. We will accordingly investigate the various effects separately.

Gain

If the feedback circuit is inoperative, then the output voltage is

$$e_3 = \alpha e_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

With the feedback circuit operative, we may determine the amplification by solving equations (1), (2) and (3) for e_3 in terms of e_1. The result is easily arrived at and is:

$$e_3 = \alpha e_1/(1-\alpha\beta) \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Hence feedback has changed the gain by the factor $1/(1-\alpha\beta)$. If $\alpha\beta$ is negative the gain decreases, if positive and less than *2* the gain increases, if unity oscillation takes place, if equal to *2* no change in gain results. The quantity $\alpha\beta$ may assume values of modulus and phase angle over a wide range, so that a complete picture of the situation can best be shown by the diagram of Fig. 2*. In this the change in gain of the amplifier in decibels due to feedback is shown for values of $|\alpha\beta|$ of from 0 to 3.0, and for phase angles between e_2 and e_4, represented by $(\Theta+\Phi)$ of from 0° to 360° The locus "0db" is of interest, as showing that values of $|\alpha\beta|$ up to 2.0 may be used without change in gain.

Stability

The output voltage with feedback is, from (5),

$$e_3 = \alpha e_1/(1-\alpha\beta).$$

and this becomes, if $|\alpha\beta|$ is large compared to unity,

$$e_3 = \Theta e_1/\beta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

This indicates that changes in the amplifier, which would change α, do not affect the output, and hence an infinite gain and phase stability has been achieved against changes in the amplifier circuit. Note, however, that the output is still proportional to β. An inspection of Fig. 2 shows that the locus B defines points through which horizontal lines may be drawn tangent to the curves. This is hence a locus of points of infinite gain stability against small changes in $|\beta|$ Similarly locus C traces points of infinite stability against small changes in $|\alpha|$. In general, it may be shown, where $|\alpha\beta|$ is considerably greater than unity, that the gain of the α circuit is stabilized by the factor of reduction in amplification, $1/(1-\alpha\beta)$, but that no stability is obtained against changes in β.

Reduction of Noise and Distortion

Let us assume that the output of the amplifier without feedback contains components not present in the source. These components may be represented by a voltage S at the output, and may be due to tube and circuit noise, and harmonic and modulation products generated in the amplifier. Hence the ratio of undesired to desired components in the output is $S/\alpha e_1$. If feedback is introduced, in order to obtain a desired output voltage the same as without feedback, the source voltage must be raised to $(1-\alpha\beta)$ times its previous value, and the ratio of undesired to desired components in the output becomes $S/\alpha(1-\alpha\beta)$. Hence the noise to signal ratio with feedback is lowered by the same factor by which the amplification is reduced.

This result has been obtained on the assumption that the voltage e_4 is amplified linearly by the α circuit. In cases where this is not nearly true an exact analysis has been previously published.[21], [27], [34].

Phase Shift

In an amplifier without feedback, the phase angle between e_1 and e_2 is determined by the angle of α, which may be denoted by Θ, and any change in Θ is reflected in the phase relation of e_1, and e_3. If feedback is introduced it can be shown that the important result is obtained when $|\alpha\beta|$ is considerably more than unity, that the phase relation between e_1 and e_3 is nearly independent of Θ, and depends mainly on the angle of β, namely Φ. The phase angle between e_1 and e_3, which we will denote by ψ, is readily arrived at from equation (5), but the value of phase-stability, against changes in the phase shift through the amplifier alone, does not seem to have been previously obtained. The value is fairly readily derived, and is:

$$\frac{d\psi}{d\Theta} = \left|\frac{|\alpha|}{(1-\alpha\beta)\cos.(\Theta+\Phi)}\right| \ldots\ldots\ldots\ldots(7)$$

Method of Equivalent Amplifier

Engineers are familiar with the theorem of the equivalent network of a vacuum tube. According to this, the plate circuit of a vacuum tube is the equivalent of a generator, of voltage μ times the grid voltage, acting through a resistance, r, known as the plate resistance. μ is known as the amplification factor of the vacuum tube. Similarly we may define an amplification factor, μ_o, and an output impedance, z_o, for any amplifier. μ_o and z_o are not restricted to real numbers, and it is more convenient to use a sense for μ_o opposite to that used for μ in the case of a vacuum tube.

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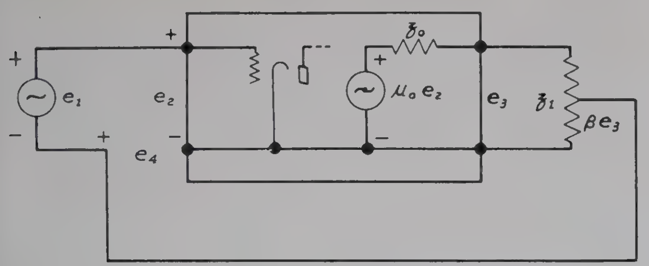
*Taken with slight changes from reference 10.



$$e_3 = \mu_o e_1 \, \frac{z_1}{(z_o + z_1)} \cdot \frac{1}{\left[1 - \mu_o \beta \left(\frac{z_1}{z_o + z_1}\right)\right]}$$

Fig. 3

Fig. 3 shows the equivalent network for an amplifier, connected with feedback, of amount β. The value of e_3 shown is readily derived, and it is seen that the factor

$$\frac{1}{(1 - \mu_o \, \beta)\left(\dfrac{z_I}{z_o + z_I}\right)}$$

represents the change in amplification due to feedback. Note that if z_o is small in comparison to z_I, then μ_o is approximately equal to $\propto$ as used above, and the expression for the change in amplification assumes the familiar form previously encountered.

We now proceed further to set up an equivalent network. We arbitrarily state that an amplifier with an amplification factor μ_o, an output impedance z_o, and a feedback ratio β, is to be represented by an equivalent amplifier without feedback, having an amplification factor μ_β, and an output impedance z_β. It is readily shown that solutions for μ_β and z_β exist, and are, in fact:

$$\mu_\beta = \mu_o/(1-\mu_o \beta) \quad \ldots\ldots\ldots\ldots (8)$$

$$z_\beta = z_o/(1-\mu_o \beta) \quad \ldots\ldots\ldots\ldots (9)$$

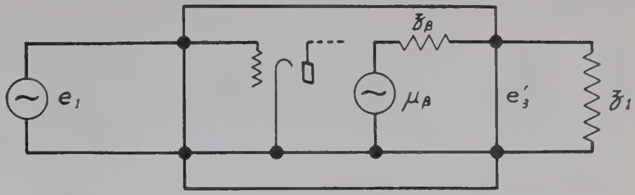
It is thus seen that the effect of using feedback is equivalent to a reduction of the amplification factor and the output impedance by the same amount, which is approximately the same as the reduction in amplification due to feedback. Note that the transconductance is unaltered. This analysis gives the engineer a physical picture of the effects of feedback. It is interesting to note that this conception is already familiar, in the use of a pentode tube with the screen connected directly to the plate, to secure operation similar to a low-μ, low-impedance triode of the same transconductance. Since the screen has a considerable μ relative to the plate, this connection merely gives the reductions in μ and r predicted by equations (8) and (9), if β is set equal to unity.

In the general case, where phase differences exist between e_2, e_3 and e_4, note that μ_β and z_β will in general be complex quantities.

Self Oscillation

Black points out that experimentally it has been found that $\propto \beta$ may assume large values in an amplifier, without the occurrence of self-oscillation, and Nyquist[3] indicates what the requirement is for such an amplifier:

The value of $\propto \beta$ of the amplifier from zero to infinite frequency is plotted in polar coordinates. If the resulting loop or loops do not enclose the point (1, 0) the amplifier will not oscillate. In circuit design this means that as the frequency is approached at which the phase shift through the amplifier and feedback path is zero (or 360°), the value $|\propto \beta|$ must be reduced to less than unity. Means for doing this are obvious to the designer, who will in general find the most satisfactory method is to stagger the frequencies at which the various inter-tube circuits commence appreciably to shift phase. In addition circuits having required phase-shift characteristics may be added.



$e_3' = e_3$ IN FIG 3 IF:

$$z_\beta = \frac{z_o}{1-\mu_o\beta}$$

$$\mu_\beta = \frac{\mu_o}{1-\mu_o\beta}$$

Fig. 4

Nomenclature

In a subject such as negative regeneration, which has not yet reached the text-book stage, it is of some importance that writers on the subject use, as far as is reasonably possible, the same conventions as regards symbols and nomenclature. It might have been thought the Black's usages could well have been adopted, but the present writer urges the adoption of the symbols used in this paper, for reasons as shown below.

$\propto$—The ratio of input to output voltage of an amplifier. Black uses μ, Dome uses μ, and $+\mu_o$. Tellegen and Henriquez use $\propto$. This seems preferable, as μ is already accepted as the symbol for the amplification factor of a vacuum tube, with a different sense and value, and as $\propto$ is the logical companion of β in the feedback circuit.

β—The ratio of the feedback voltage to the output voltage of the amplifier. Used by Black. The same symbol with the opposite sense is used by Tellegen and Henriquez. Dome, and the present writer in an earlier paper, use K, in an effort to avoid the use of Greek letters.

Θ—The angle of $\propto$. Black uses the involved symbol $\Phi\mu$.

Φ—The angle of β. Black uses the symbol Φ_β.

ψ—The total shift through the amplifier with feedback circuits operating. Black uses Φ.

Application to Radio Receivers

Sufficient theoretical discussion has been given to enable the circuit engineer to make a useful application of negative regeneration at one or more points in a receiver design. The present writer holds no brief for the use of negative regeneration, and in his own designs uses it only to a very limited extent. There is a definite use for it, however, and this field may be expected to grow as we attempt to improve receiver performance beyond present values, as tubes more suitable for circuits with feedback are developed, and as the design technique is improved. The opening up of new fields requiring wide-band transmission with restricted amplitude and phase variations, such as television, wide-band telephone carrier circuits, high-fidelity broadcasting and reception, and others, will undoubtedly call for a greater use of negative regeneration.

In applying negative regeneration in commercial designs, the circuit engineer is advised to exercise caution. The circuit performance must be known over a frequency-range many times greater than the normal pass-band. In each design adequate calculations should be made to check the measured results. Finally, the designer should not trust intuitive reasoning as he is normally safe in doing with more usual circuits. Unless he has had a considerable amount of contact with the subject, his conclusions should be carefully arrived at, and verified if possible by calculation.

Application to the Audio Amplifier

In the audio amplifier occurs one of the most satisfactory applications of negative regeneration. Modern radio receivers employ, for the most part, pentode, tetrode or class B triode tubes, which are normally worked into a load impedance made up of a loudspeaker and coupling circuits which is a function of frequency and which is only a small fraction of the output impedance of the tube. This means that the output voltage is nearly proportional to the load impedance. The introduction of negative regeneration makes the amplification nearly independent of $\propto$, and hence of the output impedance, or alternatively, the effective output impedance of the amplifier is lowered by the factor $(1-\mu_o \beta)$ as shown above. Negative regeneration may be secured in these stages by connecting resistance-capacity networks between plate and control grid, by returning the screen grid to a point on the output circuit, or by using an unbypassed cathode resistor. In this latter case the load impedance must be placed directly between plate and cathode in order to avoid an undesirable condition of so-called current feedback. Used on the output stage, negative regeneration will normally clean up distortion, which principally occurs at this point. Where loudspeaker loads are used with varying phase angle, care must be taken, however, to ensure that distortion is not actually increased, particularly near the resonant frequency of the diaphragm, where widely different values of modulus and angle occur over a small frequency range. Regeneration will also compensate for poor frequency response of the coupling elements, the output transformer for example. Some care must be exercised here, however, as while the frequency response may be improved, overloading will be a serious problem if the transformer efficiency is poor in the frequency range being transmitted.

Feedback may be used around several stages if desired. Circuit means for achieving this are obvious, and the effects mentioned above may be obtained. In addition, hum, noise and distortion arising in the preliminary stages may be eliminated. Due to the phase shifts which occur in the coupling circuits, considerable care must be exercised to prevent oscillation at some frequency outside the pass-band. This may be done as outlined under "Self Oscillation" and as described by Dome [23].

The further effect, of stability of gain against changes in amplifier constants, brought about by tube aging or voltage changes, will also be obtained. This will not generally be of much value in radio receivers except in cases of instruments used for calibration and measuring purposes.

Intermediate-Frequency Amplifier

Negative regeneration is applied with difficulty here, and in general is not useful. An interesting application is its use to broaden the selectivity of an I.-F. amplifier. This is done by using a vacuum tube in the β circuit and the variation of $|\beta|$ is then used to control the band width.

Antenna Circuit

The use of negative regeneration at this point is advanced as an interesting possibility, and not as a workable scheme without careful development work. Theoretically, in the early stages of a radio receiver, it is possible by this means to eliminate tube noise originating in the plate circuits of the vacuum tubes. This is particularly valuable in the higher frequency bands, where thermal noise is comparatively low. With suitably designed circuits, which do not seem difficult to achieve, high-frequency bands could be made to give signal-to-noise ratios as high as those obtained in the medium-frequency range. As far as the periodical literature shows, no work has yet been done in this field. This may well be the most valuable application of negative regeneration to radio receivers.

Loudspeaker

It is well known that the electrical and mechanical circuits associated with a loudspeaker may be represented by a source of oscillations, acting through an impedance, into the load of the diaphragm. The series source-impedance is made up of two factors: one is due to the electrical output impedance of the amplifier; the other is due to the mechanical coupling circuits. Application of negative regeneration to the amplifier as outlined above will reduce one factor, but will leave the other unaltered. The diaphragm will therefore oscillate with an amptitude largely determined by its mechanical impedance. The reduction of the source impedance in a loudspeaker is thus an important object, achieved in practice by the use of large magnetizing forces, large voice-coils, and close clearances. This impedance can be effectively reduced by applying negative regeneration to the amplifier-speaker system so as to include the mechanical elements in the freeback circuit. A simple method of achieving this is to have a coil wound on the diaphragm which oscillates in a magnetic field and which is not coupled electrically to the voice coil. The voltage generated in this coil by the vibrations of the diaphragm is fed back to a suitable point in the amplifier. Suppose that by this means the amplifier gain has been reduced

20 db. (10 times). If then we load the diaphragm at any frequency so that motion is prevented, the amplifier will increase its power output 100 times in an effort to restore normal amplitude of vibration. Thus negative regeneration is seen to be an important tool for the designer of electro-mechanical systems. Inexpensive and robust construction of apparatus seems possible, so that by this method a performance of these systems is possible, not easily achieved by other methods.

ACKNOWLEDGMENT—It is desired to acknowledge the assistance of Mr. E. S. Kelsey of the Northern Electric Company, Limited, in the preparation of this paper.

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Measuring the Automobile Antenna

By H. C. Forbes, Colonial Radio Corporation

The radio engineer has been called upon frequently during the past few years, to measure and to "rate" the automobile antenna. Since automobile antennas are poor at their best, it has always been important to use the antenna which provides the greatest "signal pick-up" consistent, of course, with such other requirements as mechanical reliability, maintenance of insulation, reasonable length of lead-in, and freedom from motor noise interference pick-up.

"Rating" the Antenna

The "rating" of an automobile antenna, obtained by a series of measurements of antenna characteristics, is then often used as a determinant in the choice of the particular type or dimensions of automobile antenna to be adopted.

A study of antenna characteristics by classical methods requires a knowledge of the field strength surrounding the antenna, and a measurement of the voltage induced in the antenna. The ratio of the voltage induced in the antenna to the field strength, is then the effective height of the antenna. Reactance and resistance measurements of the antenna, then permit the derivation of equivalent circuit constants, and the calculation of a figure of merit which may be used as a rating of the antenna in question.

For many purposes, absolute measurements are not necessary, and comparative results are then customarily used, thereby avoiding the necessity of determining the field strength and the effective height. Antennas may be compared by measuring their equivalent circuit constants and their induced voltages when exposed to the same electric field.

Many difficulties surround the successful accomplishment of an antenna rating. Accuracy is probably the most difficult problem. Often, in practice, it is desirable to obtain the relative merit of several antennas, to an accuracy of 10% or better. Field strength determinations, and therefore the effective height determinations, are quite commonly subject to errors of this order, so that comparative results, rather than absolute values, are generally used in practice. Even when making observations by direct comparison, careful manipulation is required, if this order of accuracy is to be secured.

The "rating" problem itself is most perplexing. It is a relatively simple matter to calculate a figure of merit rating for an antenna, but it is more difficult to build a receiver which will demonstrate that that rating is correct. Seldom is an engineer more embarrassed than when,—after extensive use of laboratory equipment, careful measurement and calculation, and a confident declaration that antenna "A" is 50% better than antenna "B",—it is found on testing with receivers, that antenna "B" is actually 50% better than antenna "A". In fact, the antenna rating problem is so inextricably associated with the design of the input circuit feeding the first grid of the receiver, that it seems of doubtful value to attempt to "rate" automobile antennas in a generalized manner at all.

If receiver input circuits were purely power operated devices,—if there were no problems of frequency coverage, tracking, non-uniform gain, circuit noise, image and IF rejection characteristics,—then receivers could and would be designed to load the antenna properly, antenna circuit resonance and optimum degrees of coupling could be utilized, and it would be possible to abstract from the automobile antenna the theoretically possible portion of the energy residing in the passing electric field, or, at least to approach these values reasonably well. If all this were possible, then a generalized antenna rating based upon the antenna circuit constants and the effective height would be borne out successfully in testing with actual receivers.

With, however, the limitations imposed upon the receiver designer by these other necessary requirements, antenna input circuits of entirely different characteristics must be used. They do not, in general, resonate the antenna circuit, or provide an optimum degree of coupling over the band of frequencies covered by the receiver, and therefore they provide a "gain" dependent upon the circuit constants of the antenna, and varying with frequency.

There are several different types of antenna input circuits in general use today, in automobile receivers, notably (1) the capacitively coupled circuit, (2) the high impedance primary resonant below the frequency band covered by the receiver, magnetically coupled to the primary, and (3) the low impedance inductively coupled circuit. It is obvious that receivers of these different types will not give results on various antennas proportional to a generalized rating on these antennas, even if they are designed especially to best suit (or "match") that particular antenna.

The point is, of course, that the engineer should prescribe the type of input circuit to be used in the receiver, and should be fully cognizant of its characteristics and limitations before attempting to "rate" the automobile antenna, if he is to avoid embarrassment.

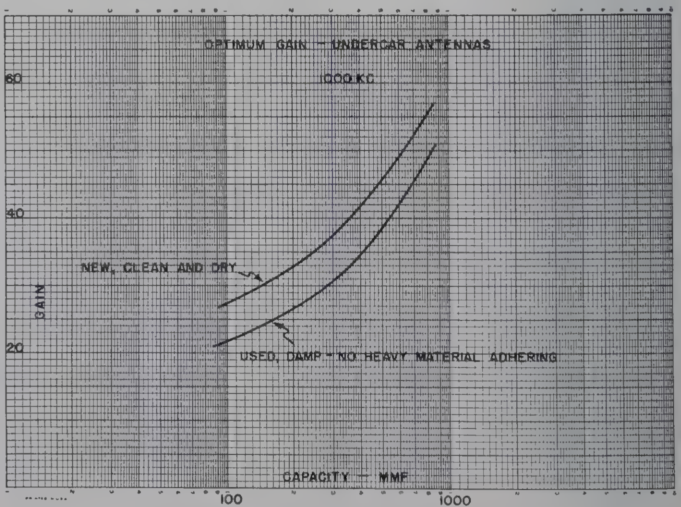

Fig. 1 (a)

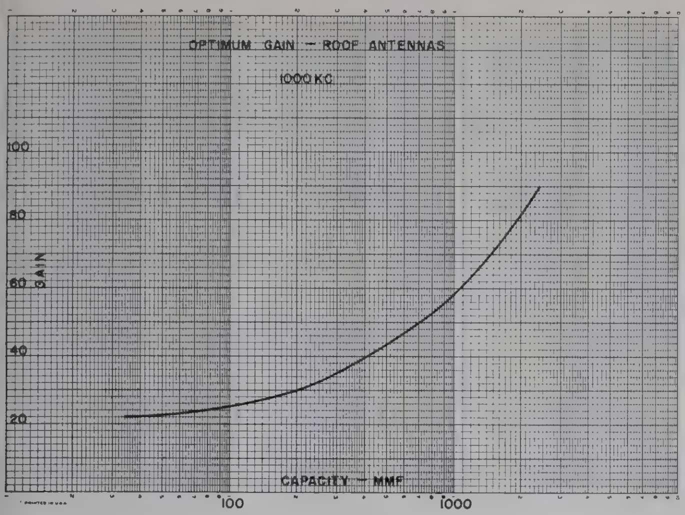

Fig. 1 (b)

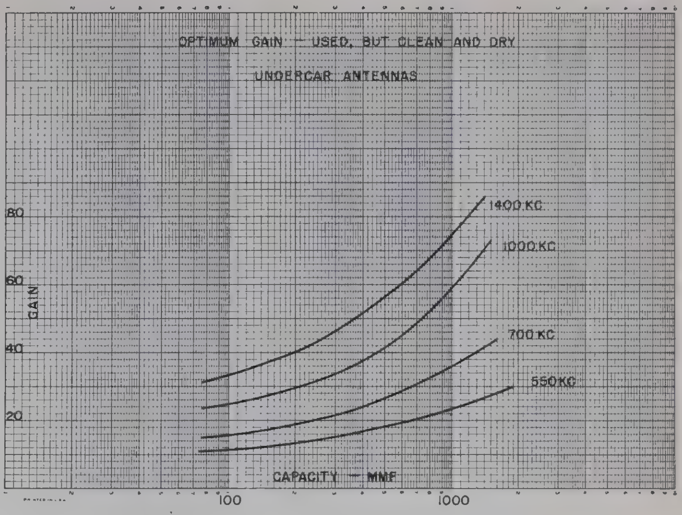

Fig. 1 (c)

Objective of Antenna and Input Circuit Design

All of the above explanation is preliminary to the statement that the engineer of auto receivers is after all really mainly interested in providing the greatest signal voltage at the grid of the first tube, subject only to the aforementioned limitations of frequency coverage, tracking, uniform gain, noise, and so on.

We have found, in our organization, that it is a much more practicable problem to combine the subjects of antenna and input circuit, than to treat them separately. Since our problems are undoubtedly similar to those presented to other design engineers, our solution, while probably unsatisfactory to the scientific mind, may be of some interest to the design engineer. Our recommendations as to the preferred choice of antennas, carry the specific statement that the choice is preferred, only if a particular input circuit (the one used in our receivers) is utilized. Similarly, if a rating of several types of antennas is to be given, so that a choice may be made from the combined considerations of cost, performance, and mechanical characteristics, the rating is likewise accompanied by a restriction to the use of a particular input circuit. Admittedly, an undesirable state of affairs, we have found no other satisfactory method of supplying practicable information on the relative merit of automobile antennas. At some future time when, perhaps, input circuits of different manufacturers will be nearly alike, and the antennas themselves do not vary from short vertical rods of 10 mmf capacity to insulated sections of car body of 2000 mmf capacity, such precautions will not be necessary, and we can safely revert to a more desirable method of treating the antenna problem.

Rating the Combined Antenna and Input Circuit

Once agreed that the antenna problem is closely associated with the problem of the best input circuit to feed the grid of the first tube in the receiver, questions naturally arise as to the factors influencing the design of the input circuit itself. This is not a paper on circuit design, and it will therefore suffice to say that having found an input circuit or circuits that meet the many requirements as to performance, and presumably as to adaptability to antennas of varying circuit constants, the next step is to obtain a characteristic curve of these circuits, showing the optimum gain at any frequency which may be obtained with a wide range of antenna capacity and resistance. (Most automobile antennas are known to have negligible inductance). It is important to note that this curve should give **optimum** gain, that is the greatest gain that can be secured with the antenna of any particular value of capacity and resistance, while meeting the various other requirements of a receiver circuit. A group of such curves are shown in Figure 1. Some input circuits are not affected as to gain to any great degree by the antenna resistance. Others are affected more at one end of the frequency band than at the other. In general, circuits of highest gain are considerably affected by antenna resistance. It is important, therefore, to use only clean, dry antennas for antenna comparisons, although it is of course of importance to know the susceptibility of any antenna and associated circuits to loss of gain through leakage resistance.

The experimental determination of the optimum gain curves of Figure 1 is a tedious job. A number of, clean, dry, antennas of similar type, but of different capacities, must be measured in conjunction with an input circuit, which has been adjusted for maximum gain at each particular value of capacity. Once this curve is available however, the rating problem becomes quite simple. All that needs be known about the antenna to be measured is the open-circuit voltage at the terminals of the lead-in, and the capacity as compared to the same characteristics of a reference antenna, measured simultaneously at the same position of the car (Broadcast stations are of course used as the source of electric field). Alternately, the field strength at the points of measurement may be determined. Reference to the optimum gain curve for the particular value of antenna capacity will give values of gain that will result from optimum design of the input circuits for those antenna capacities. The optimum gain, multiplied by the antenna terminal voltages, gives values of first grid voltages that may be produced from the two antennas. Obviously, the higher the first grid voltage, the better the combination. The general statement may then be made that an antenna and input circuit combination giving "A" microvolts at the first grid is "A/B" as good as the combination "B" microvolts.

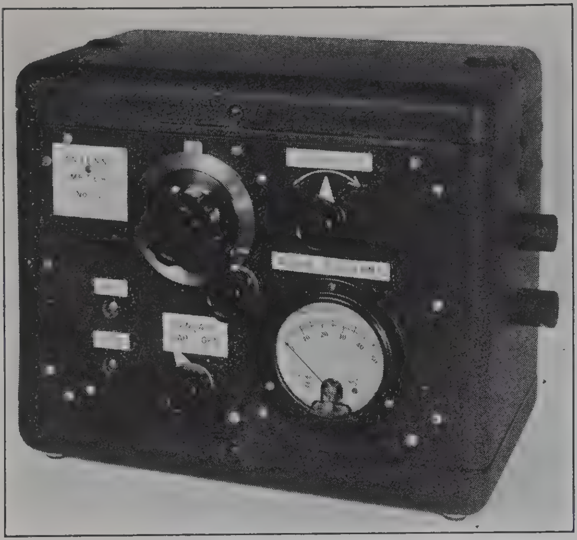

Fig. 2

Measuring Equipment

For convenience sake, an auto radio receiver with self-contained speaker was converted into an antenna measurement instrument. The instrument is shown in Figure 2, and its block diagram in Figure 3. The variable condenser, A, of the tuned circuit is not part of usual gang but is operated from a separate control. The first tube is operated without AVC. A switch is provided so that the antenna under measurement may be connected to the grid of the first amplifier tube in the measuring set, to the primary of the input circuit, or to a separate tuned circuit used for measuring the effective capacity of the antenna. In addition this switch provides for connection to the calibrating signal generator.

The impedance of the first grid circuit is maintained at a high value, and while the stray capacity in this circuit must be kept at a low value, any such stray capacity is in parallel with the antenna, and lead-in capacity, during the measurement of terminal voltage, and the resulting error is quite small. The diode current indicator is a micro-ammeter connected across any desired portion of the diode load resistor, so that a full scale reading may be obtained on any signal level. The audio system is unimportant, and is used only for station identification.

The signal generator is a conventional instrument, battery operated for use inside the automobile.

Any desired input circuit may be connected into the measuring set, or a standardized coil assembly having known or adjustable characteristics, may be inserted for measurement purposes.

Technique

In operation, the open-circuit terminal voltage is measured by placing the antenna switch in position 3 to connect the antenna (the lead-in terminals) directly to the first grid of the receiver. The diode current meter reading is noted on a broadcast signal of any desired frequency, and the calibration switch thrown to the signal generator (position 4), from which a signal of the same frequency is fed to the first grid of the receiver. The signal generator is adjusted to give the same deflection on the diode meter as produced by the test station. This value of signal is noted and recorded as the terminal voltage in the antenna. (Note that the terminal voltage is not the true induced voltage, because of the shunting effect of stray shunt capacities, including the lead-in, but it is proportional to the induced voltage. By definition, then, the input system gain is the ratio of the voltage reaching the first grid by way of the input circuit, to the open circuit terminal voltage of the antenna.) When the most suitable input system has been inserted in the measuring equipment, the antenna switch may then be placed in the antenna position (2), so as to feed the first grid via the input circuit. The new value of signal is determined by again noting the deflection of the diode current meter and calibrating it with the signal generator.

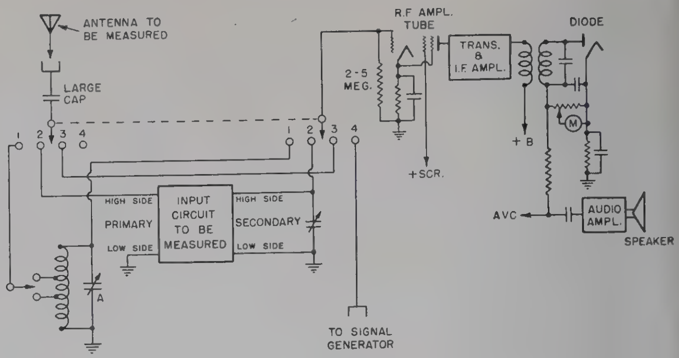

Fig. 3

Obviously, the benefit or gain resulting from the use of the input circuit designed for the antenna being measured is the ratio of the two values of first grid voltage thus obtained by actual measurement under actual operating conditions.

The effective antenna capacity is determined by "peaking" the control of "A" of Fig. 3, on the broadcast signal since condenser "A" is directly calibrated to read antenna capacity at any of the particular frequencies, employed by the broadcast stations available in the locality where the equipment is used.

Use of Standard Comparison Antenna

In practice, for comparison purposes, a "standard" antenna consisting of a vertical rod with a low-loss, low capacity, shielded lead-in is used. This antenna is placed on top of the car, with the base close to, but insulated from, the car top. In measurement all antennas are referred to this antenna as a "standard". The data so obtained may, thus, be directly compared, since all data is referred to the same "standard". By this means, measurements made at different times in different locations, using different broadcast stations as a source of signal, can be correlated and the results compared. Measurements made in this manner three years apart have been successfully checked.

Acknowledgment

The writer wishes to acknowledge the assistance of Mr. M. J. Pifer, who built the apparatus and developed the technique of making these measurements. He also wishes to acknowledge the assistance of Mr. Albert Baker, of the Olds Motor Works, whose suggestions have contributed in a large measure to the practical success of the method.

The Rational Approach to the Problem of Radio Design

By RUTH GERTH, Industrial Designer

FOREWORD

THE author is a well known industrial designer who has had experience in a wide range of product design and in writing and lecturing about the industrial design field. She is at home in the factory as well as in the drafting room, and knows the production side of the problem of creating new things. Contact with factory, engineering and sales people has given her knowledge of human nature too, so that she understands the human relations side of large production—which is no small factor in the problem of introduction of new designs. She is a past president of the Artists' Guild.

Industrial designers have not been enlisted to great degree by the radio industry, unfortunately perhaps, but they have worked wonders in other, longer-established industries. There seems to be no reason why the radio industry cannot benefit by greater use of the guidance afforded by understanding of fundamental aesthetics—at least by lessening the uncertainties which now surround radio's "art" matters. Miss Gerth has very kindly responded to the Editor's request for an article on these principles as related to radio. She points out that it is difficult, if not impossible, to tell a convincing, complete story in one short article, but we are sure that her story will be helpful to many.—ARTHUR VAN DYCK

As the radio is a comparatively new instrument there should be no traditions or precedents, and likewise no prejudices, to hamper the artist in the design of its exterior form. The designer should be able to approach the problem in a rational and straightforward manner. This has not been possible in radio design until recently, for there was delay in giving radio an identity of its own. In the early days, the engineer necessarily turned all his attention to the development of the mechanism. To protect this mechanism from dust and damage he covered it with a box. When the instrument became an accepted and necessary home appliance, it was natural for the box to be replaced with a cabinet associated with traditional living room furniture. Often the buyer transferred the chassis to some cabinet which he already possessed. This served to disguise the radio, and the lack of unity between the mechanism and the housing retarded the creation of a radio which could be considered a fine instrument in itself, worthy of its own identity. During the first ten years, purely technical advances were so rapid and so radical in effect that stable design in any one form was not possible. There would have been little use in designing separate loudspeakers to be permanent things of beauty, when their life was so short and their performance so—well, so-so. But now technical development has reached the stage where fundamental changes are infrequent and where it, in most cases, plays second fiddle to appearance.

It took a long time to erase from the minds of manufacturers and buyers the idea that a radio must be camouflaged, and some of the evils of this attitude still influence the designs of today. In the past couple of years there has been definite action to produce radio forms as new in concept as the mechanisms which they house. This is a step in the right direction, but now it is important to perfect the appearance of this form.

This exterior form, however, should not be designed independently of the chassis, for it is not merely a jacket added after all the engineering problems have been solved and the arrangement of details determined. Its shape must grow from within as well as from without. There are functional parts with which the artist must deal, and since technical considerations may determine the arrangement of many of the details of interior mechanism, it is essential that engineer and artist work in close collaboration.

The primary job of the artist is to work with the engineer, considering and solving all problems pertaining to appearance, in order that the final product may be presented to the public in its most favorable light. How successfully he moulds the physical and visual aspects into an harmonious whole is the largest factor in determining the success of the product in sales.

Of course, there are many factors other than those directly related to appearance which must be considered when designing a radio. The artist must keep in mind manufacturing and sales costs, competition, market trends and contemporary design. Only those phases directly applicable to the exterior form will be discussed herein.

The solution of any design problem can be approached through a logical method of procedure, in other words through a "rational approach", and when such method is adopted, the problem loses most of its seeming mystery, uncertainty, and difficulty. There are three fundamental phases in this rational approach: the psychological, the practical, and the aesthetic. Each has a definite place in the solution of the problem and all three must be used before the resulting product will be eminently satisfactory. They are so closely interwoven that it is difficult to tell where one leaves off and the other begins. The psychological phase of the approach determines the inherent merit of a product, the practical decides the ease of functioning, and the aesthetic provides the whole with those intangible qualities which give pleasure and satisfaction in ownership. Designed from these three angles, a radio will express its function vitally, simply and beautifully.

The Psychological Viewpoint

Considering radio from the psychological standpoint, we know that it is a fine, important, necessary adjunct to modern life. Therefore it should be designed, housed and known as such. In the past, though, an entirely different picture was created in the subconscious mind of the buyer. Radios were something one disguised and hid from view in lamp bases, behind false book covers or in writing desks or treasure chests, thus denying them their just possession of a dignified place in the modern scheme of living. Today radios have arrived at the point where they are given the quality of integrity by having an identity of their own.

The days of attempted disguise still influence to some extent the new designs. There is still an endeavor to hide the functional parts even though they are such an important part of the instrument.

A radio is not merely a cabinet from which issue programs received from broadcasting studios. It is an instrument WHICH MUST BE MANIPULATED before it is possible for programs to come forth. The controls and dials are the important devices whereby the user is enabled to play a part in the broadcasting system, even though it is only the small part of searching for stations, making his selection of programs and adjusting the tone of those tuned in. In the eyes of the user the knobs and dials assume vital importance, for they make possible HIS control of the mechanism. Psychologically they should be made dominant in design, and be given more importance than necessary rather than less. These functional devices characterize the radio, and if dramatized by size and position they add a vital interest to an otherwise commonplace cabinet. In fact, the point is proven by the sales success, about two years ago, of those manufacturers who pioneered the large dial.

The Practical Viewpoint

From the practical angle of approach the designs of the dials and control need complete revision in concept and execution. There has been some improvement in the placement of these controls but the dials are most inadequate to use. The only reason for their existence is that they are to be read by the person tuning in a program. Yet this is almost impossible. The placement is such that the observer must crouch in ungainly fashion to bring the dial into his line of vision. The numerals are not legible in character and are too small to be read without the aid of a magnifying glass. The positions on most of the dials are indicated by a pointer which swings from a central pivot. This, of course, means that the end of the pointer must describe an arc, but the markings often fail to follow this arc and are arranged in squares, hexagons or any queer shape which pleases the fancy of the manufacturer. Often the dials are surrounded by escutcheons which are so fancy in shape and ornamentation they become more important than the dials, making it difficult to concentrate on the numerals enclosed within its boundaries. If straightforward thinking were applied to this problem of dials there would be no attempt to 'style' them by the addition of trick shapes and distracting escutcheons. The practical approach would make proper placement, adequate lighting and legibility the prime requisites—and the resulting dials would be more satisfactory from the aesthetic standpoint as well.

A practical solution to any design problem will invest the resulting product with a directness of expression which is in itself beautiful. Beauty is not 'styling' applied to the surface treatment of an article, it is the result of the arrangement of the lines, forms and masses which make up the optical aspect. When practical considerations are properly and adequately taken care of and decide the arrangement of the elements, the object will possess beauty. A large scale example of this principle is the George Washington Bridge. The sheer, thrilling beauty of it lies in the structural lines, forms and masses which were the result of practical construction principles being communicated to steel and concrete. No amount of stone facing, no addition of decorative features, would add one whit to its beauty. The simple radio dial falls into the same category in the matter of design. No fancy escutcheon, no trick arrangement of numerals, no unusual shape add to its aesthetic merit, for these additions are illogical and impractical.

The principle of the practical approach should also be applied to the design of the control knobs. Commonly they are difficult to use. They are so small in diameter the fingers must be cramped to grasp them and operating them necessitates awkward wrist-twisting. To improve the utility of these controls the diameter should be increased to more adequately fit the hand, say 2½ or 3 inches. The heighth could then be reduced and the resulting controls would appear as large flat discs. These would be more convenient to the hand and much more satisfactory to the eye. They would no longer appear as ugly, projecting nubbins or bumps upon the smooth surface of the wood. For still greater convenience the disc controls might be placed on each side of the cabinet, then there would be no need to bend the wrist in order to operate them. In fact, the whole arm would assume a more natural position.

The principle of practical and logical construction should be expressed in the shape and arrangement of those parts which form the structure of the cabinet. A characteristic feature of many models this year defies this principle. Mouldings which form the base and which should act as an enclosing support for the four sides of the cabinet are suddenly cut asunder for no apparent reason. No matter how well built the radio might be the eye is not satisfied with this appearance of a break in the structural lines of the base. To the observer the front of the machine seems about to slip down to the floor, for the front section of the base has been removed and no longer supports the center panel. In the present models the mouldings which form the finishing edge of the top of the cabinet receive the same queer treatment as though the designer had suddenly become capricious and removed a piece of moulding. Between these severed parts of the cabinet a plain panel is inserted. This inserted section is not independent in manufacture, construction or function, so there is little excuse for such design—yet there it is like an afterthought.

The Aesthetic Approach

It is not enough that the radio shall be a well engineered practical article. Our machine age makes it possible for many factories to produce similar articles with similar machines and similar conditions. With so many factors being equal in manufacturing, competition is levelled. Radio manufacturers present to the consumer products of similar character, performance and price. So the main basis of differentiation is the appearance. Today this must be of the highest order, for in the last few years there has been a radical change in the buying habits of the consumer. Moving pictures, magazines and advertising have educated the buyer to a finer appreciation of better looking products. Consequently, the appearance factor assumes great importance.

Radios which will please the eye of this discriminating buyer must adhere to the principles of beauty. There are many principles but I will discuss here only those which are of most importance in radio cabinet design.

The accepted definition of design is that it is the orderly arrangement of line, form and mass to suit a given space or purpose. The keyword of that definition is the word 'orderly'. True beauty is the exemplification of the world order. That order is all around us, we see it, feel it, experience it continually. Nothing is static, everything is dynamic and an expression of rhythmic action. The beauty of nature is the result of rhythmic order communicated to material, the result of growth in logical order from cause to effect.

When man creates new forms to function for the needs of today, he must create in tune with the world order if the results are to be satisfying physically and mentally. If he uses lines and forms which do not tune in, if the adjustment of them is not according to the order of growth, he produces discord and corresponding ugliness.

The buyer need not be versed in the matters of design principles to react to the ryhthm which he experiences mentally through the eye. He is as sensitive to that rhythm as he is to the ryhthm which he hears through music. As he listens to music he feels the rhythm to such an extent he probably keeps time with hand or foot. This reaction is subconscious, but let a wrong note or rasp of static enter the music and his whole body will respond to the discord. The response is no longer a subconscious one, the break has made him conscious of discord and he reacts with irritation. In viewing the exterior form of a radio instrument he again experiences subconsciously the rhythm of line and form and mass. He feels the sweep of line if it is right, but a wrong curve jolts him and he is dissatisfied.

Just as there are natural laws which form the basis for engineering principles, so there are basic laws which the artist uses in determining the shapes of things. The first principle of design is the order of dynamic proportion. In nature we find this exemplified in all its forms. A stalk of snake grass, the snow flake, the chambered shell are all composed of like sections in varying dimensions. The human figure follows this same order.

Common sense would dictate this principle, too, for it stands to reason that elements which are unequal in importance and function should not be equal in size. Each should have its own dimension but the proportions should not vary too greatly for then they would seem unrelated to each other. The repetition of like dimensions would produce a monotonous effect.

The harmonious relation of proportions is to be found in all art of the past and present. The Greeks had a mathematical formula by which they achieved the classic art of their day, but in every period the best artists have felt this rhythm and communicated it to their designs. If the radio of today is to possess the beauty which it deserves, the proportioning of its individual elements must accord with this principle of dynamic dimensions.

There is another phase of this matter of dimensions which is known as scale. In a cabinet it is particularly applicable to detail and features or ornamentation, but little attention seems to have been paid to it in current models. The bulbous bulges which are so prevalent in this year's models are entirely out of scale with the size of the machine itself. And in combination with the small detail of dials, escutcheons, knobs and mouldings they appear coarse and vulgar. In fact these bulbous designs remind one of a famous failure in motor car design which cost the manufacturer several million dollars through its failure to please the consumer. From the appearance standpoint, the curves of a sleek, trim figure are always more appealing than the rotund bulges of the fat dowager. This is as true of a radio as it is of the female figure, yet most of the models this year incorporate these bulbous bulges.

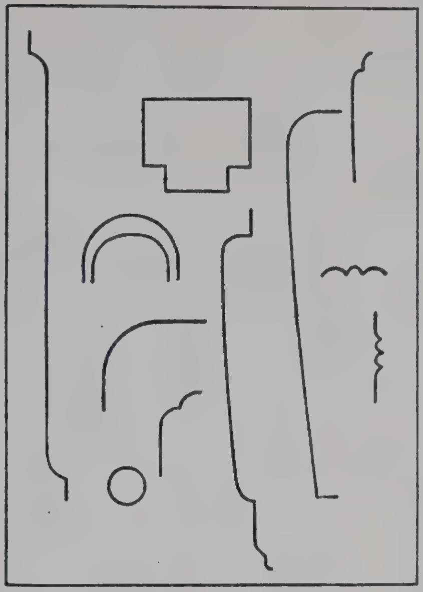

Fig. 1

Care must be exercised in the combination of details which are purely decorative. The scale of the ornamentation of an escutcheon should not be picayune in relation to the mouldings. Mouldings must be in scale with the grill which protects the loudspeaker opening. Control knobs often have small scale markings which are not in relation to the scale of other markings on the cabinet, and this is not only poor aesthetically but it also tends to make the knobs seem still more insignificant in appearance. The eye is not pleased if it must jump from one dimension to another instead of being led by gradual steps in gradation.

Another principle which we find in nature is the REPETITION of line and form (differentiated from CORRECTNESS of line and form as mentioned above). The snowflake is, in its design, an orderly and harmonious arrangement of hexagons or parts of hexagons. The jagged, rugged shape of the oak tree is echoed in each branch, twig and leaf form. In the human figure this unity of shape holds true. The character of the whole is repeated in all its subordinate parts. The male figure is composed of squared lines which form the head, the shoulders the hands and feet. Graceful curves form the female figure. If parts of the two types of the figures were transposed the effect would be inharmonious and grotesque. Imagine the lovely oval head of a girl growing upon the square shoulders of a young man. The lack of relation in the character of lines and forms would be painfully noticeable at once.

In Figure 1 there are sketched the various and unrelated shapes observed in one current cabinet design. The absence of a unifying idea throughout is self evident. Perhaps the most repeated fault in this direction is in the design of the escutcheon plate in relation to the dial or to the panel on which the dial is placed. The fretwork placed over the loudspeaker opening is seldom a design which corresponds to other detail.

Only when the character of line and form is repeated throughout the component elements of an object is there a feeling of unity. This unity is important for it conveys the impression that the subordinate parts are harmonious and coordinated parts of the whole.

Balance is the principle which dictates the placement of details to produce the feeling of a state of equilibrium. The eye is not satisfied if one side of the cabinet seems weighted down with detail in comparison with the other side. As this weight is purely an optical aspect it is not determined solely by the amount of detail, nor by the space occupied by the detail. Dominance, color and interest all carry weight optically. So the dial, through its interest, will serve to balance a larger area occupied by the loudspeaker opening. The receiving sets on the market this year, especially the table models, have this principle pretty well defined in the arrangement and placement of dials and speakers.

Through the application of these principles instruments may be designed which will possess a high degree of aesthetic merit, but one other quality must pervade the whole before they are eminently satisfactory for the U. S. market. That is the quality of timeliness in design. Magazines, moving pictures and advertising promote the present mode of living and all things particularly applicable to this mode. Thus the reader becomes conscious of a definite contemporary feeling exemplified in all products worthy of mention and he or she looks for it when purchasing any new article, whether it be a new hat or—a new radio. Speaking radio wise, the new product must be in tune with general design movements and feelings of the time, that is, it must have "timeliness."

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Oscillator Stabilization

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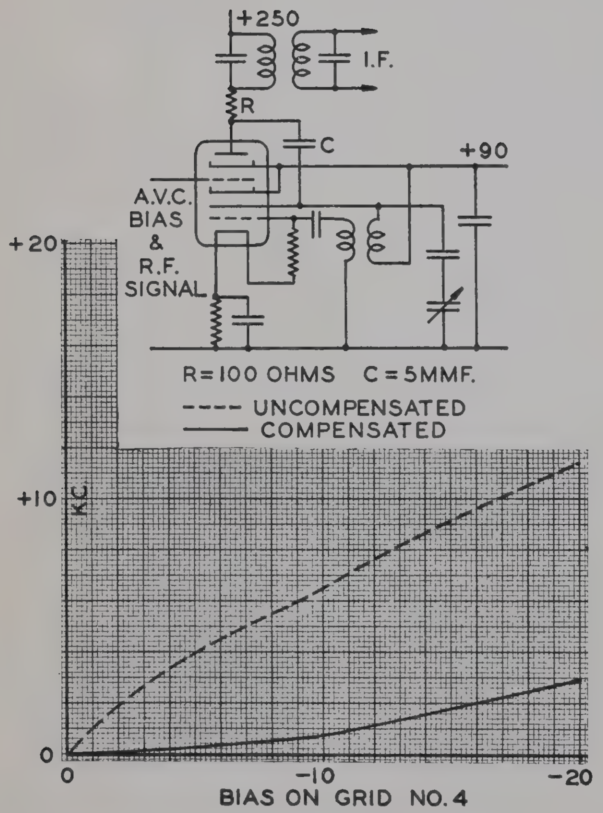

FIG. 18

Another circuit can be used, in which the phase angle between oscillator grid and anode will change very little, when the plate resistance of the tube is changed. This can be done, if the plate circuit is tuned instead of the grid circuit. This circuit arrangement, which itself has much less frequency drift than the conventional circuit, gives excellent result, when a compensation network is used. Fig. 18 shows measurement made at 18 Mc and the circuit diagram employed.

The circuit arrangement will also compensate for frequency drift caused by changes in the B-voltage. For instance the frequency will deviate but 2 kc instead of 12 for a change in the B-voltage from 200 to 250 volts.

In Europe a so called triode hexode is often used, in which the AVC voltage will affect the oscillator frequency comparatively little. This tube makes it possible to build a very stable oscillator for changes both in AVC and B-voltages.

The above mentioned arrangement for stabilizing oscillator frequency can of course be used for all kinds of oscillators in transmitters, measuring instruments and so on. In the laboratory of Aga-Baltic in Sweden a 1000 K.C. oscillator was built, whose frequency deviation was limited to only 2 or 3 cycles for a change in the B-voltage from 80 to 250 volts.

R. M. A. STANDARDS SECTION REPORTS

The year now closing, characterized, as it was, by floods and other natural impediments to the smooth flow of product between Association members and by the wasteful procedures of labor controversies further interrupting the economical production of the nation's supply of radio equipment, has most pointedly emphasized the value of strong, well-knit, cooperative organization of the engineering phases of the Association's activities.

It is not surprising, therefore, to find that, as 1937 draws to a close, the many Standards Committees of the Association have been especially active during the year and that marked progress in the direction of developing industry standards can be reported. A brief report of the work of a number of the committees is given below.

Committee on Vacuum Tubes

R. M. Wise, Chairman

As the activities of this committee are conducted largely by sub-committees the following summary is presented:

1. Sub-Committee on Tube Numbering,
   MR. E. W. WILBY, Chairman

   This sub-committee performs the important function of assigning RMA tube numbers to tube manufacturers in this country and in several foreign countries. When there is a conflict in reservations, Mr. Wilby arranges for interchange of data between the interested companies in order to avoid duplication of types.

2. Sub-Committee on Tube Limits,
   MR. S. W. SEELEY, Chairman

   This sub-committee has done excellent work in standardizing methods of measuring important tube characteristics on which tube manufacturers desire to set uniform limits. An outstanding example was the measurement of pentagrid converters, for which measuring equipment was devised which has been very useful in enabling a satisfactory agreement to be reached on centers and limits. Another current problem is the question of measurement of Class B tubes, where it is also necessary to decide what characteristics are of importance in the application of the tube before it is possible to agree upon limits among tube manufacturers.

3. Sub-Committee on Tube Testers,
   MR. LESLIE J. WOODS, Chairman

   This committee has been active for some length of time in devising recommendations and establishing limits for tube testers. It is expected that the report will become final at the next meeting, completing the work of the sub-committee.

Other sub-committees are active from time to time, such as the Sub-Committee on Measurement of Interelement Capacitance (Mr. Wilby), and Sub-Committee on Tube Bases (Mr. D. F. Schmit.)

Committee on Sound Equipment

Hugh S. Knowles, Chairman

The most recent standards adopted by this committee and approved by the General Standards Committee cover the important mounting dimensions of all the more popular size loud speakers. A color code which includes lead colors for from one to three loud speakers has been adopted. This was not available in time for the earliest design releases last year and members are urged to give this their immediate attention for new designs. Needless confusion, expense and delays in production will result from continued use of the former tentative standard which was used for several years but never given final approval.

There is an urgent need of performance standard for amplifiers. The adoption of such standards has been delayed principally because of (a) a negative general membership vote on the output power—distortion standard proposed in 1933, (b) some genuine technical differences of opinion (c) reluctance of some commercial departments to restriction of claims and (d) inadequate cooperation. It is felt that the technical problems can be met and cooperation of the committee members and general membership is urged in overcoming the others. There is interest in a cooperative attitude toward the adoption of microphone mounting standards as well as performance specifications. Standards covering these matters should be proposed in the near future.

Speaker performance specifications are a controversial matter and at the moment it appears unwise to crystallize measuring technique by adopting any standard method. This is a necessary concommitant to response measurements since the response curve obtained depends on the method employed in securing it. In spite of the difficulties it is hoped to propose at least a recommended practice in this field since the ultimate performance of every complete receiver and sound system depends on the loud speaker behavior and no specification for this important link is at present available.

Committee on Component Parts

L. C. F. Horle, Chairman

The **Sub-Committee on Fixed Moulded Resistors,** under the chairmanship of Mr. Jesse Marsten, having in mind the need for ever lower noise levels in radio sets and also the imminence of practical television and its probable dependence on suitable resistors, is at the moment directing its attention to the development and standardization of two important measuring methods, i.e., the measurement of the noise-generating characteristics and the frequency characteristics of fixed moulded resistors. Additionally, it is working toward the establishment of standard values of resistors for type testing and is moving in the direction of the adoption of a system of resistor color coding to supplement the R. M. A. color coding system now in general use.

The **Sub-committee on Fixed Capacitors,** with the leadership of Mr. Harry W. Houck, is developing a system of color coding of fixed capacitors and is continuing to be occupied with the establishment of a rational basis for the voltage and life rating of fixed capacitors. The former of these projects is being directed in such a manner as will maintain it in harmony with the work on color coding by the Sub-committee on Fixed Moulded Resistors, in the interest of simplifying and standardizing the color coding schedules of the Association.

The **Sub-committee on Electrolytic Capacitors,** of which Mr. J. I. Cornell is Chairman, is moving in the direction of bringing its own membership and the set manufacturing membership into agreement on many dimensional and purely mechanical characteristics of electrolytic capacitors, notably, with respect to unit sizes, mounting details, connection terminals and the like. A standards proposal based on the work of the committee will be offered for discussion at the Rochester meeting.

Mr. Arni Helgason, Chairman of the **Sub-committee on Power Transformers,** reports that his committee will present to the General Standards Committee a formal standards proposal already approved by the membership establishing standard nomenclature and rating in the interest of the simplification of the preparation of purchase and testing specifications.

The **Sub-committee on RF and IF Transformers,** Mr. Monte Cohen, Chairman, has this Spring made a good start toward the establishment of standard and generally acceptable methods of coil and high-frequency transformer acceptance testing. The work here is one not alone of securing agreement amongst the makers of the parts here concerned but of bringing the experience and desires of the set manufacturers to bear on the problem to the end that the usual process of "building to sample" may ultimately be replaced by the specifying in unequivocal terms of such units as are here of interest. Reports of further progress will doubtless be made at the coming Rochester Fall Meeting.

The **Sub-committee on Ballast Resistor Units,** Mr. Victor Mucher, Chairman, is considering a system of designation and type numbering for this type of unit. Further discussion of this project is scheduled for the Rochester Meeting of this committee.

The **Sub-committee on Variable Control Resistors,** of which Mr. H. A. Williams is Chairman, having developed a generally acceptable mechanical standardization of "large" volume control units, will carry on in the development of similar standardization on the newer and smaller types of units. Additionally, it is momentarily in the process of evolving standardization on a limited number of displacement-resistance characteristics, i.e., resistance curves, again, to simplify purchase specifications and minimize replacement stocks.

The **Sub-committee on Rotary Circuit Switches** (Wave Change Switches), Mr. Henry G. Richter, Chairman, has partially developed the mechanical and dimensional standardization of wave change switches. A standards proposal has been formulated and will be circulated to the industry shortly.

The **Sub-committee on Tube Sockets,** of which Mr. W. C. MacFadden is Chairman, has made a good beginning in the development of standard tolerances of especial importance in any case where mating parts, such as vacuum-tube bases and vacuum-tube sockets, as are here involved are concerned. The work of this sub-committee is being directed into intimate contact with an appropriate sub-committee of the Committee on Vacuum Tubes and in close relation to the experience of the makers of tube base parts.

Substantially all of the Committees of the Standards Section are scheduled to meet during the Rochester Fall Meeting to carry forward the many projects now in progress and to initiate new and useful work.

■ ■ ■

Variation of Permeability of Iron Cores with RF Signal Level

Continued from Page Eight

out these tests and, hence, the phenomenon here reported is the result of the dependence of the permeability of the core on the A. C. magnetomotive forces. In these measurements, the A. C. magnetomotive force for 100 volts of A. C. across the coil was approximately 6 ampere-turns, assuming 200 turns on the coil and one millihenry inductance. As may be seen in Figure 2, this voltage level at the coil produces an appreciable change in tuning with magentite cores. Several finely divided iron cores were measured and produced results similar to that shown for carbonyl iron. Of the cores tested, only those constructed from magnetite ore showed permeability changes of relatively serious proportions.

It should be further noted that the change of frequency with increasing signal level was in the direction of lower frequencies. That is, the permeability of the core increased with signal level. It is believed that this indicates that the change of permeability is taking place over the initial bend in the B-H curve of the material in which region, it will be remembered, the slope of the curve increases with increasing field intensities. This provides a reasonable explanation of the phenomenon here reported and, incidentally, confirms the thought that at the signal levels encountered in the high frequency circuits of a receiver there are not likely to be any saturation effects in powdered iron cores.

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Measurements of Characteristics of Automobile Receivers

By Harry Lyman Philco Radio and Television Corp.

The many and varied types of automobile antennas which have come into common use during recent years is strongly indicative of the fact that much thought and effort has been applied to the problem of finding the most suitable type of antenna for use on automobiles. The very wide range of types of antennas which has thus been developed has added much to the problems of the set designer since each general type of automobile antenna is likely to have characteristics which markedly distinguish it from other types and thus make necessary detailed studies of these characteristics in order that suitable rational receiver designs may be made. It is the purpose of this paper to describe the methods and the equipment which the writer and his associates have developed for the measurement of automobile antenna characteristics.

A simple classification of the types of automobile antennas in general use and approximate data on their constants may be of value and certainly will be found of interest in emphasizing the need for the careful measurement of antenna characteristics as an essential portion of automobile receiver design.

Thus, the roof antenna, usually consists of a piece of insulated chicken wire, built into the top of the car. The insulated steel insert, is commonly a solid steel sheet in the place of the fabric top of early automobile designs. The undercarriage antenna may be a collector installed under the running board, or it may be the running board itself if properly insulated from the frame of the car. The monorod antenna usually consists of a rod supported from two to four inches above the top on the center line of the body, or one of the many variations of this general arrangement. The cowl antenna, which is, as a rule, a collapsible rod about 60 inches in length is commonly mounted on the side of the cowl either vertically or at an angle to conform with the lines of the car. In addition to these several types there is the type of antenna comprising the shorter vertical (or nearly so) rod mounted above the center of the top of windshield of which a typical example is the antenna used by Ford. This is a rod, adjustable in length between 17 and 30 inches. This rod may be turned down, to clear obstructions, by turning a knob inside the car. Insulated spare tire supports and insulated rear compartment doors are used as antennas to a rather limited extent.

As for the characteristics of these several types of antennas it will probably be interesting to note that the roof antenna which, as installed in a fabric top, was one of the first satisfactory automobile antennas to be used, has capacities which range from 90$\mu\mu$f to about 700$\mu\mu$f.

The insulated steel top insert antenna is characterized by a very low effective height, a very high capacity, ranging from 1500 to 3000 $\mu\mu$f, and, in general, a rather poor power factor,—as high as 8%. However, because of the high capacity, relatively high gain antenna transformers can be designed to operate with them.

The undercarriage antenna usually has a capacity falling between 100 to 250 $\mu\mu$f. This type of antenna has the disadvantage of collecting mud, slush, and ice from the road, which changes the characteristics in varying degrees. In addition, it is very much more susceptible to tire static than aerials mounted at higher levels on the car.

The monorod, or over-the-top antennas, such as the Ford antenna, are all of very low capacity, some being as low as 15 $\mu\mu$f and seldom is an antenna of this type as high as 40 $\mu\mu$f in capacity. Indeed the capacity of the lead in with which it operates is very often much larger than the capacity of the antenna itself.

Spare-tire-support antennas and insulated rear compartment doors when used as antennas have been of relatively low efficiency. The cowl antennas are of relatively low capacity, being about 20 to 30 $\mu\mu$f and relatively great effective height. These antennas are usually mounted in such locations as favor a low capacity lead-in to the set and are thus characterized by very high effective heights.

The wide range of mechanical forms and details and the equally wide range of electrical characteristics represented by these types of antennas is, of course the result of the fact that the interest of the automobile designer is in devising such antennas as will beautify the car of which it is a part or, at worst, will not detract from the beauty of the car; while, on the other hand the first interest of the radio designer is to so choose the antenna as to result in best performance. As is usual under the conditions of such conflicting interests, compromise must be resorted to in order, in this case, to yield an antenna of reasonably good performance and satisfactory appearance. In order that the best compromise may be made it is essential that the characteristics of the antenna be readily measurable, especially as they influence the design of the antenna transformer of the receiving system. Indeed not infrequently it is only through the minutely careful design of the antenna transformer is it possible to provide satisfactorily high sensitivities and satisfactory signal to noise ratios.

The methods and apparatus used by the writer and his associates for this purpose have been developed through the several years in which they have been concerned with the measurement of automobile antennas and in its present form incorporates revisions and improvements in accuracy and convenience evolved from the series of equipment previously designed and widely used. It is designed to measure the two major characteristics of automobile antennas, namely effective height and capacitance.

The general requirements to be met by such measuring equipment as this are:

1. Rapid and convenient set-up and manipulation.
2. A minimum of computation for the interpretation of the data.
3. Capability of use with the field produced by any local broadcast station without pre-determination of field strength of the broadcasting station.
4. Provision for mounting the equipment on the car in order that the directional effects of unknown

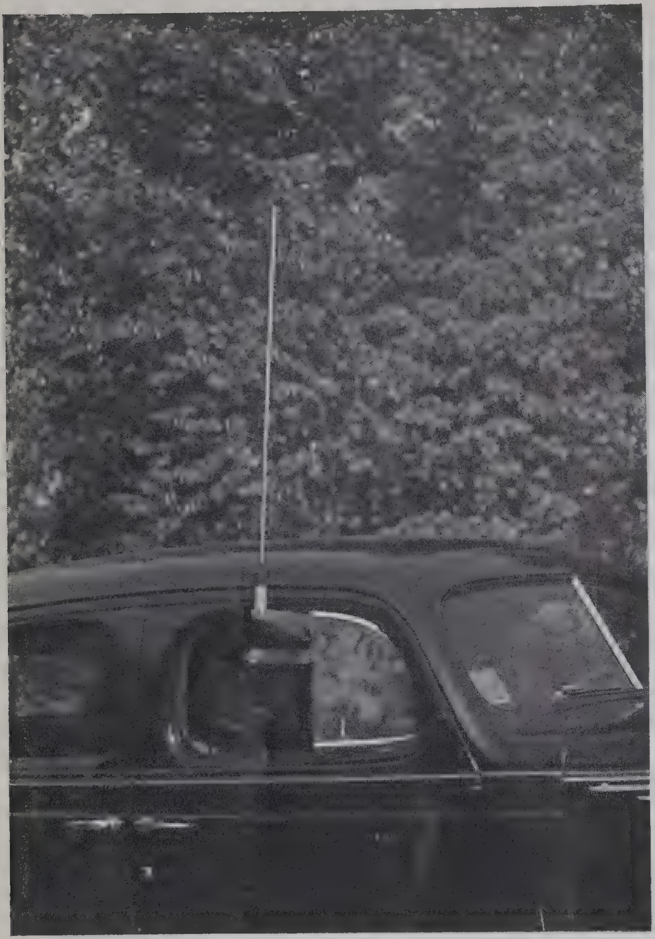

Fig. A

antennas may be observed and measured by driving car about an open field.

5. The use of a comparison method employing a standard, non-directional antenna of known characteristics for reasons of obviousness of interpretation.
6. Simplicity of operation to facilitate its operation by untrained personnel.
7. Easy portability.

The measurement system here discussed comprises a vertical rod which is used as a substantially non-directional standard antenna (shown in figures A and B) of known effective height, a voltage indicator and means for the precise and convenient measurement of capacitance at broadcast frequencies. The directional effect of the antenna produces an error of not more than 1%. The standard antenna and the antenna to be measured are alternately switched to the linear voltage indicator shown in Figure C. The voltage readings are corrected for the shunt capacitance of the shielded connecting leads. The ratio of the corrected readings multiplied by the effective height of the standard antenna thus gives the effective height of the unknown antenna.

For determining the capacitance of antennas and cables, an oscillator operating at 550 k.c. is employed in the measuring equipment. A variable condenser in the tank circuit of the oscillator is carefully calibrated to indicate the external capacitance which may be applied across its terminals. The antenna to be measured is connected directly across this condenser and capacitance of the variable condenser is reduced until the oscillator is again operating at 550 k.c. as shown by a resonant bridge circuit which detects extremely minute departures in oscillator frequency from 550 k.c.

By setting up a standard antenna calibrated in terms of actual effective height or voltage delivered to the first grid of the voltage indicator, it becomes possible to compare the antenna under investigation with it and thus quickly measure the characteristics of interest.

The circuit properties of an antenna of major interest are: capacitance, power factor, and effective height. The inductance of an automobile antenna can usually quite safely be neglected as a design factor when the antenna is operated in the standard broadcast frequency band. The capacitance measurements should include in addition to measurement of the capacitance of the antenna alone, measurement of the shunt capacitances, such as shielded cables and insulating supports, and the like. The antenna may in practise, be operated under various conditions in which event it is necessary to measure the capacitance under all of these various conditions. Similarly the effective height of the antenna is measured for all conditions of operation by repeated comparison with the standard antenna.

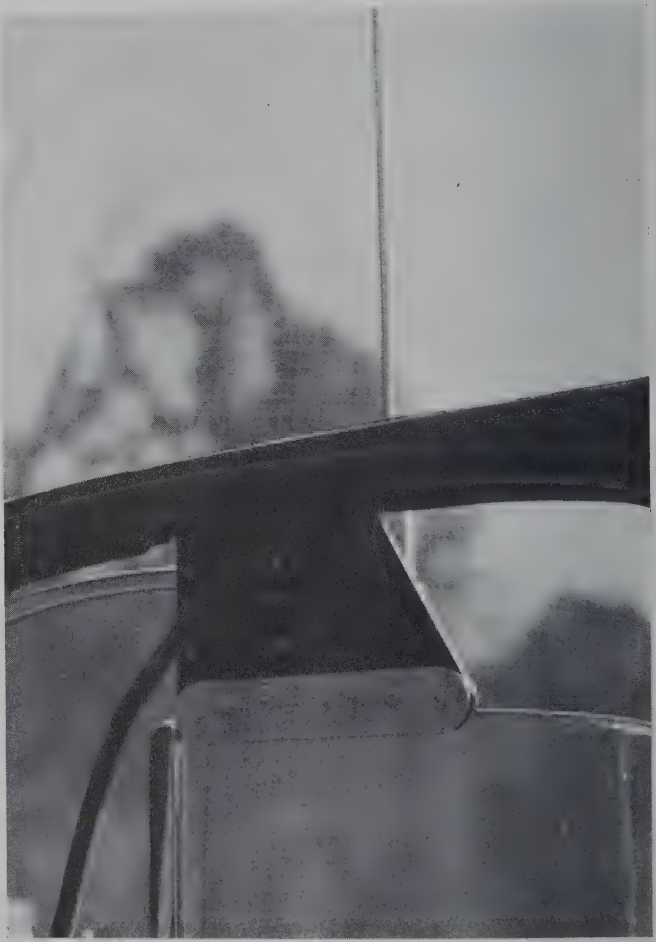

Fig. B

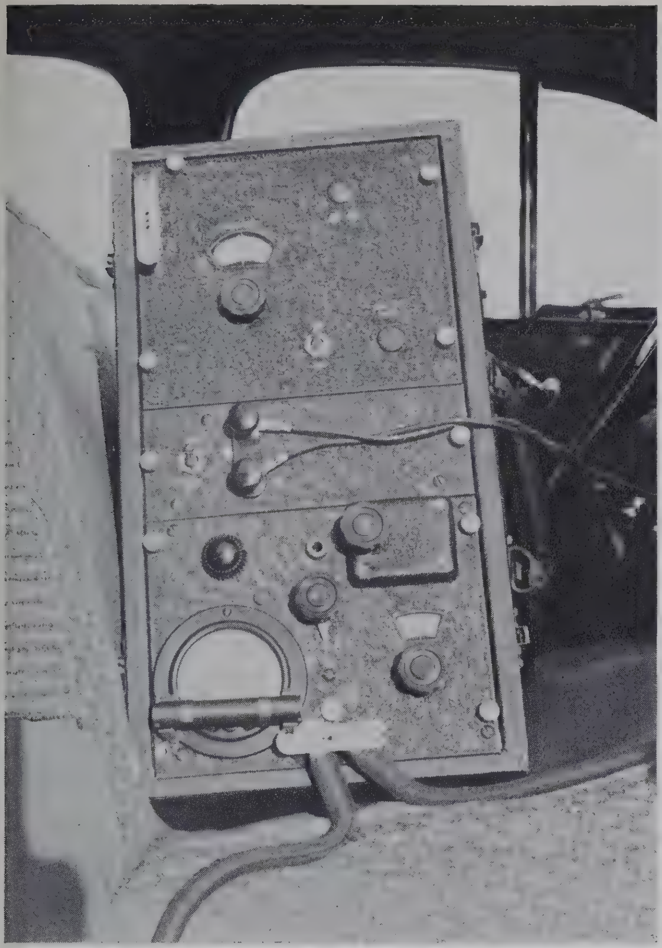

Fig. C

The measurement of the power factor was, in earlier work, done at the same time as the capacitance measurements, but experience has shown that it is sufficient to measure the capacitance and effective height of the antenna. A portable R.F. bridge is, however, always available in the event that it becomes necessary to measure some new design of antenna requiring special examination. In general, only the very poorest of antennas have power factors as high as 8 per cent. Normally, automobile antennas have power factors around ½ to 3 per cent, and its effect on the gain of the conventional antenna transformer may therefore be neglected. In the investigation of a particular antenna, measurement is made of the capacitance of the shielded lead both with the antenna connected and disconnected. Measurement is then made of the relative voltage, at the voltage indicator, of the antenna system in per cent of the voltage of the standard antenna. From these capacitance and voltage measurements of the unknown antenna, its effective height in terms of the standard antenna may then be computed.

The standard antenna is a rod 32 inches long and about three-tenths of an inch in diameter; it is supported on a bakelite panel by a horizontal aluminum bracket about 8″ long. The bakelite panel may be fitted in the door of the car between the top of the door and the door glass as shown in Figures A and B. A shielded cable serves to connect the standard antenna to the R.F. voltmeter.

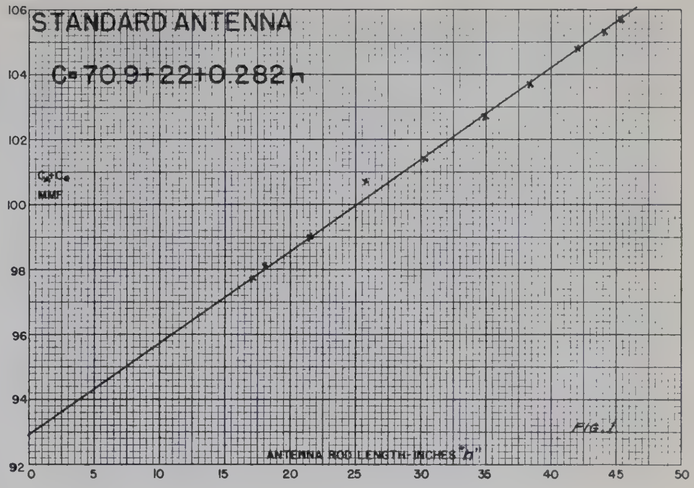

Fig. 1

The variation of capacitance with changes in height of the standard antenna is shown in Figure 1. The capacitance there shown comprises the total capacitance shunting the grid of the first tube in the R.F. voltage indicator and including, of course, the capacitances of the range of rod lengths there shown. The capacitance of the rod is very approximately 0.282 $\mu\mu$f per inch length. The capactiance of the shielded lead and the antenna mounting is 70.9 $\mu\mu$f, while the input circuit capacitance of the voltage indicator is 22 $\mu\mu$f.

In determining the effective height of the standard 32 inch rod, the procedure is to measure the relative voltage at the grid of the first tube in the voltage indicator for various lengths of rods. Then the quantity VC/h is plotted against the rod length "h" as in Figure 2. This figure gives the data gathered in measurements made on three types of cars: Plymouth, Packard 120, and Studebaker. From this data it is evident that at $h=o$, the quantity VC/h has a value of 145, which is equivalent to an initial height,—h_e,—of 26.3 inches. This value of the initial height is due to the "height effect" of the car body. In making these measurements the base of the antenna was approximately 61 inches above the ground on all three cars. Thus, effectively, the rod has a length of 32+26.3 inches or 58.3 inches. The total capacitance of the antenna, cable and voltage indicator is 101.9 $\mu\mu$f, and while the capacitance of the antenna only is 9.02 $\mu\mu$f, the effective height of the standard antenna is, therefore, given by

$$h_e=\frac{58.3}{2}\times\frac{9.02}{101.9}\times 2.54=6.55 \text{ C.M.}$$

To justify the steps taken in this computation of h_c, let us review some fundamental antenna theory. For this, we set

h_e = Effective height
H = Field strength
E = Hh_e = Potential induced in antenna
h = Length of rod
h_c = Height effect due to car

$$h_e = \frac{(h+h_c)}{(\ 2\ )}$$

$$E = \frac{H(h+h_c)}{(\ 2\ )}$$

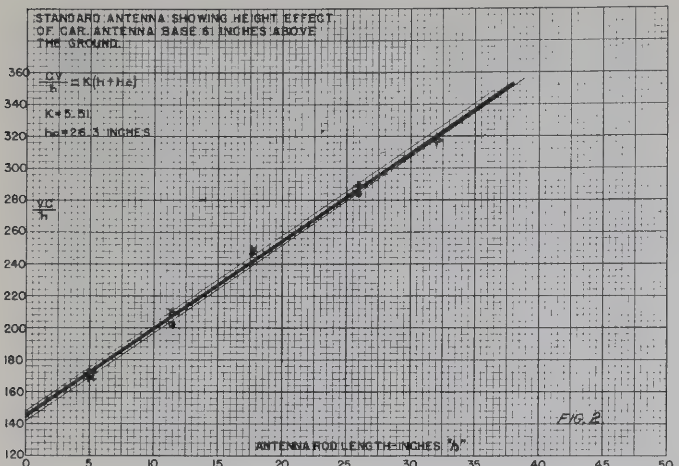

Fig. 2

V = Potential appearing at first grid of voltage indicator.

C_r = Capacity of rod per unit length

C_a = Capacity of rod $= C_r h$

C_o = Capacity of lead-in and instrument

Then $V = E\left(\frac{C_a}{(C_a + C_o)}\right) = \left(\frac{C_r h}{(C_a + C_o)}\right) H \frac{(h+h_c)}{(2)}$

Rearranging the terms:

$$V \frac{(C_a + C_o)}{(h)} = \frac{(C_r H)}{(2)} \quad (h+h_c)$$

Since with the given standard antenna and in a given signal field strength $\frac{CrH}{2}$ is a constant and we may simplify this equation thus,

$$V \frac{(C_a + C_o)}{(h)} = K(h+h_c)$$

In the measurement procedure outlined above every quantity in the last equation is measured except K and h_c. These may be found graphically very easily by plotting $V \frac{(C_a + C_o)}{(h)}$ against h, as was shown in Figure 2, and taking the derivative or determining the slope of the resultant curve. This derivative is K, since $\frac{d\left(\frac{VC}{h}\right)}{d(h)} = K$ and h_c may be determined from,

$$h_c = \frac{CV}{hK} - h$$

This brings us up to the point of computing the actual effective height of the antenna at the voltage indicator first grid. The equation for the effective height,

$$h_e = \frac{(h+h_c)}{(2)}$$

does not take into account the effect of the shunt capacitance of the shielded lead and voltage indicator, which reduces the effective height by the ratio of the antenna capacitance of the total circuit capacitance. Thus we have

$$h_e = \frac{(C_a)}{(C_a + C_o)} \; \frac{(h+h_c)}{(2)}$$

Since we now have the standard antenna height, we will for purposes of illustration assume that a typical antenna, which may or may not include a shielded lead-in, is to be measured as to its capacitance and effective height. Let the capacitance of the antenna be assumed to be

$$C_A = 42 \ \mu\mu f.$$

while the instrument capacitance is $C_o = 78 \ \mu\mu f$. In this is included the capacitance of a connecting shielded lead-in as well as the capacitance of the measuring instrument itself.

Assume, further, that the voltage indicator shows $V_x = 95$ when the standard is adjusted to give $V = 100$. The effective height of this antenna is then

$$h_x = h_e \frac{Vx}{V} \left(\frac{C_A + C_o}{C_A}\right) = 17.8 \text{ C.M.}$$

In this work it is found of value to use as an efficiency factor, for low capacity antennas, the product of the antenna capacity and corrected voltage ratio divided by 100. Thus an antenna having a capacity of 100 $\mu\mu f$ and an effective height of 6.55 C.M. has a rating of 100. This is predicated on the empirical basis that the gain of the antenna transformer is roughly proportional to the antenna capacity. The figure of merit of the combination of the antenna associated with its transformer is, of course, represented by the product of the effective height and the transformer step-up.

In greater detail, the equipment as shown in Figure C and D consists of two principal units, namely; the R.F. voltmeter-capacity bridge and the standard antenna. The R.F. voltmeter-capacity bridge unit is built into a portable case and has three separately removable units. They are:

(a) R.F. voltmeter
(b) Power pack
(c) Capacity bridge

These units are individually shielded by aluminum cans that are bolted together and held inside the case.

The R.F. voltmeter unit is a three-tube tuned radio-frequency amplifier, using two type 78 and one type 6B7 tubes; the circuit diagram is shown in Figure 3. As there shown, the input to the first tube is untuned and the grid circuit is closed to ground through a 0.5 megohm resistor. The voltage for the antenna or bridge is applied directly to the grid in order to avoid the alignment difficulties which accompany the use of a tuned input circuit. The diode of the 6B7 is used as a linear rectifier for the voltmeter indicator circuit, and a 100-microampere meter is the indicator. The diode current is linear with respect to input voltage for currents above 5 microamperes. A small bias is used in the diode circuit to make the meter deflection directly proportional to the input voltage. A variable resistor in the cathode circuits of the three amplifier stages is used to control the gain and thereby to change the range of the meter. A three-point selector switch is provided in the grid circuit of the first tube to allow selection of any one of three circuits; i.e., the unknown antenna, the standard antenna, or the capacity bridge.

The power pack is a conventional vibrator plate supply unit working from 6 volts and delivers about 180 volts. Except in special cases, power is obtained from the battery with which the automobile is equipped.

The capacity bridge as shown in Figure 4 consists of an oscillator designed to operate at 550 k.c., a variable

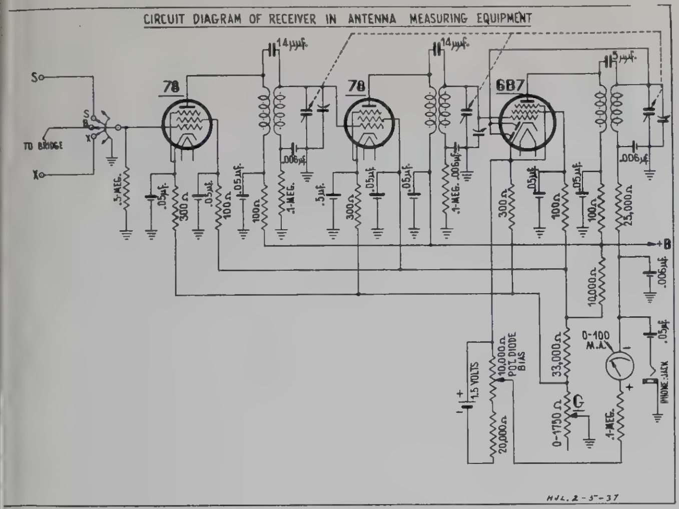

Fig. 3

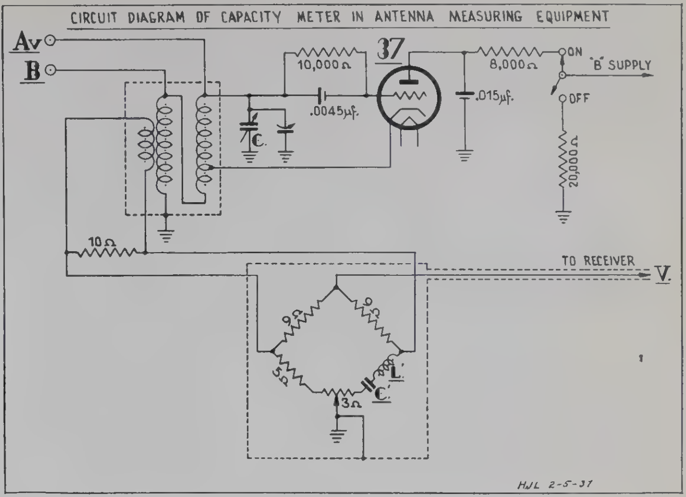

Fig. 4

condenser calibrated in terms of reduction in capacitance below that required for operation at 550 k.c., and a bridge type resonance indicator. The variable condenser is in the tank circuit of the oscillator and has capacitance range of approximately 220 μμf. The change on capacitance is a linear function of rotation over a scale length of 430 divisions out of the total of 450 divisions. There are alternative connections for measuring capacitance labelled "A" and "B". In the "A" position the capacitance to be measured is connected directly across the variable condenser, and is thus directly indicated by the calibration of the condenser. In the "B" position the capacitance to be measured is connected across a portion of the oscillator tank inductance, so located that the unknown capacitance is approximately 10 times the capacitance reduction of the variable condenser, to effect 550 k.c. operation. The capacitance calibration is not quite linear in the "B" position, as is shown by Figure 5.

The output of the 550 k.c. oscillator is introduced into a bridge-type resonance indicator, the circuit diagram of which is shown in Figure 5. The bridge has three resistive arms and one resonant arm, consisting of a series resonant circuit tuned to 550 k.c. The output of this bridge is measured by means the R.F. voltmeter. When the bridge is balanced, or nearly so, there is a very sharp dip in the voltage output, as the oscillator frequency is adjusted through 550 k.c. The center of this dip is the point of exact resonance. The instrument is very sensitive to capacity changes in the oscillator tank circuit and adjustments may easily be made to 0.1 μμf.

The cables used in making the measurements on the standard antenna and unknown antennas are constructed of 8 layers of cotton braid over a 7/.004 bronze conductor within a copper braid shield covered with a protective cotton braid. The whole cable is thoroughly impregnated against moisture by a high melting point wax. While these cables are very stable with regard to capacity throughout the time required for a series of measure-

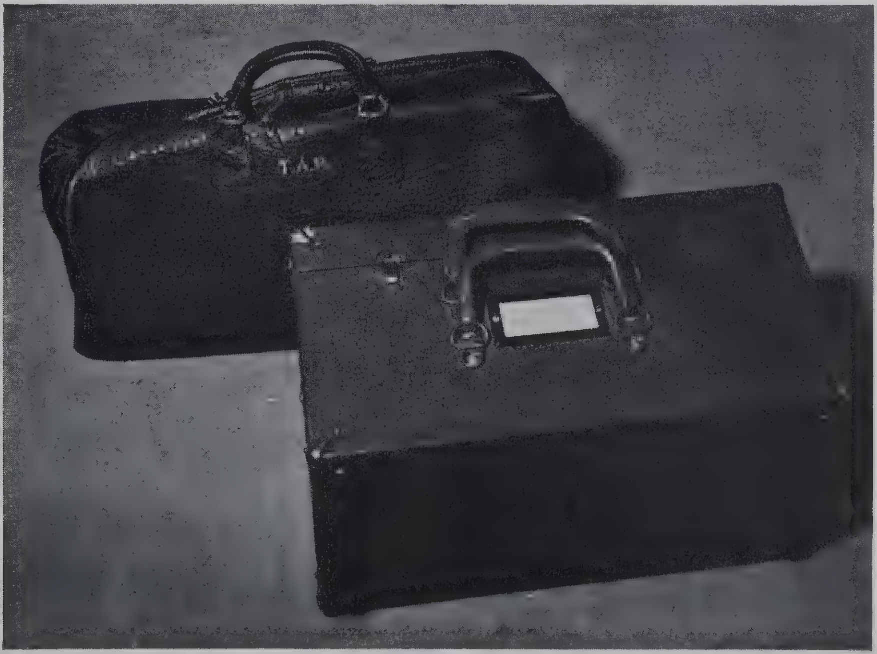

Fig. D

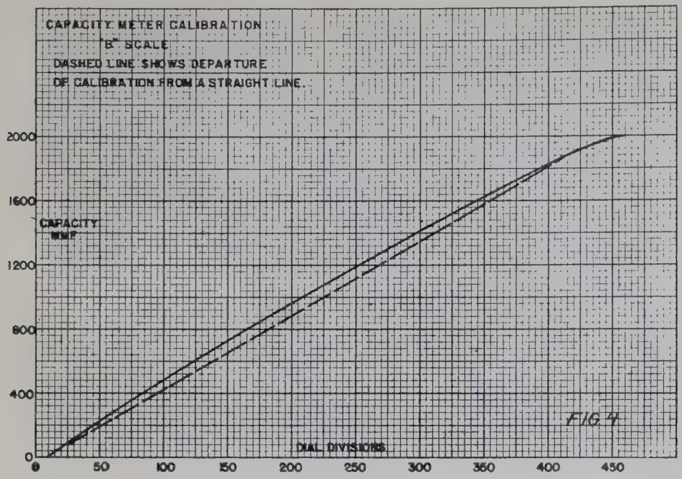

Fig. 5

ments, they must occasionally be checked and corrections made accordingly since they are not completely stable over long periods of time.

It can be said that this equipment is simple and convenient to operate. The results are reliable and can be duplicated with very small error. A setup can be made from inside the car and complete measurements on a given antenna can be made in fifteen minutes or less. The equipment is rugged enough to withstand reasonable shocks without serious damage; indeed, after nine months use in the field, the capacity bridge was checked and found to be within 0.5 per cent of the original calibration. The complete outfit weighs about 20 pounds, which allows of easy handling in setting it up for measurements or in carrying it about. It is so designed and built that a person not ordinarily accustomed to special measuring apparatus has little difficulty in its use. It has met with general approval.

I wish to acknowledge the ideas and inspiration given me in this work by Mr. J. H. Pressley of Philco Radio and Television Corporation.

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Types of Tubes

The number of types of receiving tybes in production and use in the United States of America has long since become so great that many radio engineers have been unable to keep in mind even the more important characteristics of them. Inevitably that tends to make the engineer suspicious of his retentive capacity. However, a review of the tubes in use will show that no ordinary individual could possibly be expected to remember the characteristics of all of them. He will know definitely that there are too many of them, and he will note that the business of publishing handbooks on tube characteristics is flourishing.

It may be of interest to note that during the past year or so the radio industry has been manufacturing and selling 238 different types of receiving vacuum-tubes. It is important to note, as well, that 40 of these types account for more than 75% of the tube sales. Also it is interesting that the 2-volt battery-type tubes comprise both 10% of the number of types and 10% of tube sales.

Arthur Van Dyck.

Internal Cross Modulation in Radio Receivers

H. C. TITTLE, Colonial Radio Corporation

Cross modulation is commonly understood to refer to a condition wherein the modulation of one radio frequency signal is transferred to the carrier of another signal, without the need for any definite or restricted relation between the two carrier frequencies. The phenomena received a good deal of attention several years ago, before the advent of the variable mu tube.[1] After the variable mu tube came into general use, the attention of radio engineers was occupied with the then more pressing problems. During the last two years, and possibly because of the rapid increase in the number of broadcasting stations and their power, cross modulation has been receiving attention again.

The "false input" or spurious signal phenomenon has been given less attention. By it is meant the apparent reception of a signal, at a frequency or dial setting where no station should be received. It is observed most often in metropolitan districts having two or more strong local stations. It can be identified by careful attention, in which case the observer will find that the spurious signal is carrying a modulation which is a mixture of those of two other signals. He will also observe that when either one of these two stations shuts down, the spurious signal disappears. This phenomenon in reality comes from the same cause as cross-modulation, as will later be shown.

Another type of interference which has been receiving attention lately is known as "external cross modulation."[2] It is found only in districts of exceptionally high field strength, and requires that there be some rectifying element external to the receiver and in its vicinity. This source of cross-modulation will also give rise to false input signals.

It is now recognized that all of these types of interference result from the same basic cause, and are explainable on the assumption that a non-linear element exists somewhere in the radio broadcasting system comprising the transmitter, the transmission path and the receiver. If the source of interference is external to the receiver, it is called "external cross modulation." If the source is within the receiver itself, it is convenient to use the term "internal cross-modulation." Spurious signals may originate either externally or internally, and, for the purposes of this paper, are regarded as aspects of the single general phenomenon of cross modulation.

Confining our attention to those operational irregularaties which may originate within the receiver itself and remembering that cross-modulation or spurious signals require at least two incoming signals for their production, it is obvious that the effect is most likely to originate at the first tube of the receiver. If the receiver is of the superheterodyne type, the first tube may be either an r-f amplifier or a translator. It is well known that the translator action may give rise to other undesirable effects such as "image interference", second harmonic tweet and types of spurious responses that are important at frequencies approximating that of the second harmonic of the intermediate frequency. Except for some notes on the translator action, the discussion here given will be confined to the case in which the normal function of the first tube is that of an r-f amplifier.

The situation of interest occurs when two signals of different frequencies are present at the grid of the first tube. One of these signals may be the desired one, or that to which the receiver is tuned, while the presence of the other results in interference or cross-modulation. Or the receiver may not be tuned to either one, when spurious signals resulting from interaction between the two signals are found. If a false or spurious signal falls at a frequency on which no real signal is present, the mixed modulation of both real signals is usually heard. If a real signal is present on this frequency, additional beat notes are heard and the reception of the real signal may be seriously interfered with.

A physical picture of the conditions which can cause such effects may be obtained by reference to Fig. 1. Assume that the curve (A, B) represents the relation between r-f plate current (I_p cos pt) resulting from signal voltage, (P cos pt), as a function of control grid bias potential. The operating point (Ec_o) then determines an alternating plate current (I_{p_o} cos 2 pt). If about this operating point there is applied a modulated signal [Q(1+m cos at) cos qt], as indicated, the plate current of frequency $(p/2\pi)$ is caused to vary as shown. With the operating point, (Ec_o), in a region of curvature, the resulting plate current has an amplitude variation at the modulating frequency of the interfering signal. Thus, a modulated wave is produced and the original un-modulated wave has been cross-modulated. If the point of operation had been chosen so that the total grid swing occurred over a straight portion of the curve, no cross-modulation would have occurred.

A physical picture of the production of spurious signals of frequencies such as $(2q \pm p)/2\pi$ is a little more difficult to develop. Referring again to Fig. 1, suppose a voltage, (Q cos qt) is applied at the operating point (Ec_o). The plate current (I_p cos pt) will vary as shown. Because of the curvature about the operating point, this variation is unsymmetrical about the horizontal axis, accounting for second harmonic and other multiples of (q). A component of the plate current must, therefore,

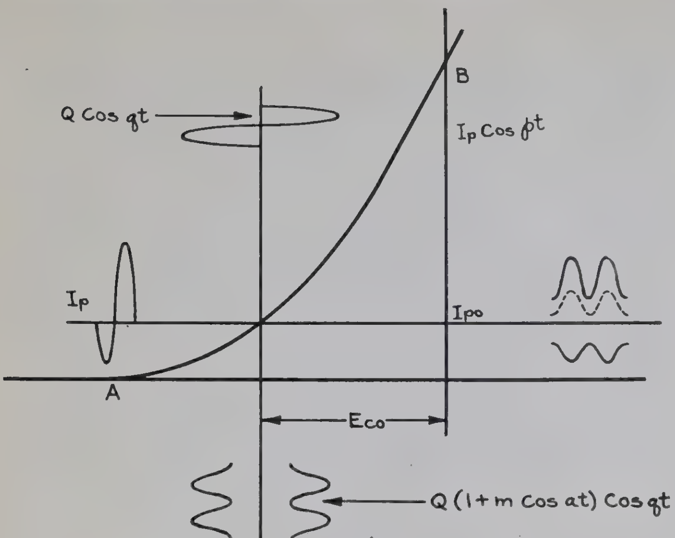

Fig. 1

be (kP cos 2qt cos pt) which accounts for a new frequency $(2q-p)/2\pi$, since

$$\cos 2qt \cos pt = \tfrac{1}{2} \cos (2q-p)t + \tfrac{1}{2} \cos (2q+p)t.$$

By considering the variation in plate current as expressed by a power series in terms of the grid voltage,[3] all current components which can result from interaction between two signals are readily found. The variation in plate current is

$$i_p = b_1 e + b_2 e^2 + b_3 e^3 + \quad . \quad . \quad .$$

where $b_n = \frac{1}{|\underline{n}} \; \frac{\partial^n I_p}{\partial E_g^n}$

One signal will be considered as un-modulated $[e_1 = (P \cos pt)]$ and the other modulated $[e_2 = Q(1+m \cos at) \cos qt]$.

So $e = e_1 + e_2$

Substitution in the series and expansion will result in identifying the following expressions which are of interest. All components listed are derived from the first and third terms.

Cross Modulation

(1) $b_1[P + (3b_3/b_1)Q^2 m \cos at] \cos pt$ (1)

Spurious signals resulting from cross-modulation:

(2) $\frac{3}{4} b_3 PQ^2(1+2m \cos at) \cos (2q-p)t$ (2)

(3) $\frac{3}{4} b_3 P^2 Q(1+m \cos at) \cos (2p-q)t$ (3)

In reality, second harmonic distortion of the modulation frequency is always present with the cross modulation of (1), and with the spurious signal of, (2), but has been neglected here in the interest of clarity. Spurious response (3), however, is shown complete insofar as it can be derived from the third order term.

Another undesirable effect, known as "modulation rise," may also result when the receiver is tuned to a strong modulated signal. In this case the signal has the same carrier frequency as the original but it has a higher degree of modulation. It is,

$\frac{3}{4} b_3 Q^3(1+3m \cos at) \cos qt$,

when neglecting second and third harmonic distortion of the modulating frequency. It adds to the desired response and produces an increase in the effective modulation.

Remembering that $g_m = \frac{\partial I_p}{\partial E_g}$, it is seen that the cross-modulated signal (1) may be written

$$gm \left[P + \frac{m \, \partial^3 I_p/\partial E^3_g}{2 \, gm} Q^2 \cos at\right] \cos pt \qquad (4)$$

Thus, the degree of cross-modulation is directly proportional to the third derivative of the static characteristic at the operating point and to the square of the amplitude of the originally modulated signal.

Similarly, the spurious signals of (2) and (3) are proportional to the third derivative of the static characteristic at the operating point, and to the product of the amplitude at the tube grid of one causing signal by the square of the amplitude of the other.

The third order effect will also produce spurious signals of $(2p+q)/2\pi$ and $(2q+p)/2\pi$ frequencies, but these are usually so far from the frequency to which the receiver is tuned that they are of little practical importance. The second order term, $(b_2 e^2)$ will account for spurious signals of frequency of $(p-q)/2\pi$ and $(p+q)/2\pi$ which also are of little practical importance. Effects of higher order than the third are usually so small as to require little attention.

Summarizing the above discussion briefly, it is seen that the third and other higher odd ordered effects will account for (a) cross-modulation; (b) an important series of spurious signals [(2p–q) and (2q–p) effects]; and (c) modulation rise.

All spurious signals resulting from the third order effect are proportional to the square of the amplitude of one of the causing signals and to the first power of the other. Any method of reducing the magnitude of (b_3) would be expected to reduce all of the undesired effects.

If the static plate current-grid voltage characteristic were parabolic, its mathematical expression would have no third order term and such a tube could obviously produce none of these undesired responses here discussed as long as the grid voltage swing did not exceed the limits of the parabolic relation. Tubes of this character are not available with such other properties as would make them satisfactory for use as radio frequency amplifiers in broadcast receivers.

The so-called exponential tube would be one having a static plate-current grid bias characteristic which is an exponential curve. Its equation would be of the form

$$I_p = A \, e^{b(E_g - E_{c1})} \qquad (5)$$

where (A) and (b) are design constants, (Eg) is the total grid voltage, and E_{c1} is the minimum operating grid bias voltage. For such a tube, all terms including the third exist, but the relative magnitude of the first to any other could by design be made as great as desired. A properly designed tube having a truly exponential characteristic would therefore provide a solution to the problem here considered. Tubes now available to the radio set designer manufacturer are unfortunately far removed from this ideal as will be shown below.

Another approach to a solution of the problem of cross modulation and its accompanying spurious signals is to provide additional selectivity ahead of the first tube so that one of the signals is reduced in magnitude, thereby profiting by the fact that the spurious signals are proportional to the product of the amplitude of one signal and the square of the amplitude of the other. Obviously also, if the amplitudes of both signals at the grid of the first tube are reduced, improvement will result, since the undesired effect would decrease faster with decreasing signal amplitude than does the desired and first order effect.

EXPERIMENTAL STUDY OF THE THIRD ORDER COEFFICIENT

The relative merit of pentode tubes such as the 6K7G may be determined at audio frequencies through the use of a distortion free audio signal source and a wave analyzer. The tube is supplied with appropriate electrode polarizing voltages and a resistance of several thousand ohms is connected in the plate circuit. The wave analyzer input is the drop across this resistor. Means is provided for adjusting the control grid bias to any desired value. An audio voltage which is known to be free from distortion is applied to the control grid. The wave analyzer will then receive a voltage of fundamental frequency as well as any harmonics of the fundamental which are generated within the tube.

By tuning the wave analyzer first to the fundamental output and measuring its magnitude and then to the third harmonic, the relative magnitude of the third harmonic to the first may be determined for any grid bias voltage. The third harmonic output is proportional to the third derivative of the static characteristic. For all observations, the input voltage should be kept constant at a value not greater than 1 volt.

If the input voltage is (e_1) and the output of fundamental frequency is (E_{o1}) the fundamental frequency voltage ratio is given by $A = E_{o1}/e_1$. Assume that for this value of input a third harmonic voltage of (E_{o3}) is found. This is the spurious or undesired output voltage. The same magnitude of output at the plate would have been obtained if an input voltage of third harmonic frequency had been applied with magnitude $e'_3 = E_{o3}/A$. The voltage (e'_3) thus determined is the equivalent spurious input for the operating conditions used in making the observations. The grid bias voltage which gives the lowest equivalent input is the one which will give the least undesired response relative to the fundamental. Note that the equivalent input is $e'_3 = \frac{E_{o3}}{A} = \frac{E_{o3}}{E_{o1}} e_1$ showing that it is not necessarily low when the third harmonic output is low, that is, the important thing is **not** the magnitude of the spurious output but its relative magnitude with respect to the fundamental output for the same operating condition.

Data taken in the manner outlined on the type 6K7G tube are shown in Fig. 2. It is seen that this tube is far from ideal with respect to spurious response or cross-modulation. Data are also shown for a type 235 tube which has an approximately exponential static characteristic. The superiority of the 235 over the 6K7G is obvious.

The type 6B8G is not customarily used as an r-f amplifier because of its rather close cut-off characteristic. It is however exceptionally free from spurious output within its operating range and this range can be extended if the screen is supplied through a self-regulating resistor, as is indicated in Fig. 4. When used in this manner, it provides a great improvement over the 6K7G, as is shown in Fig. 2.

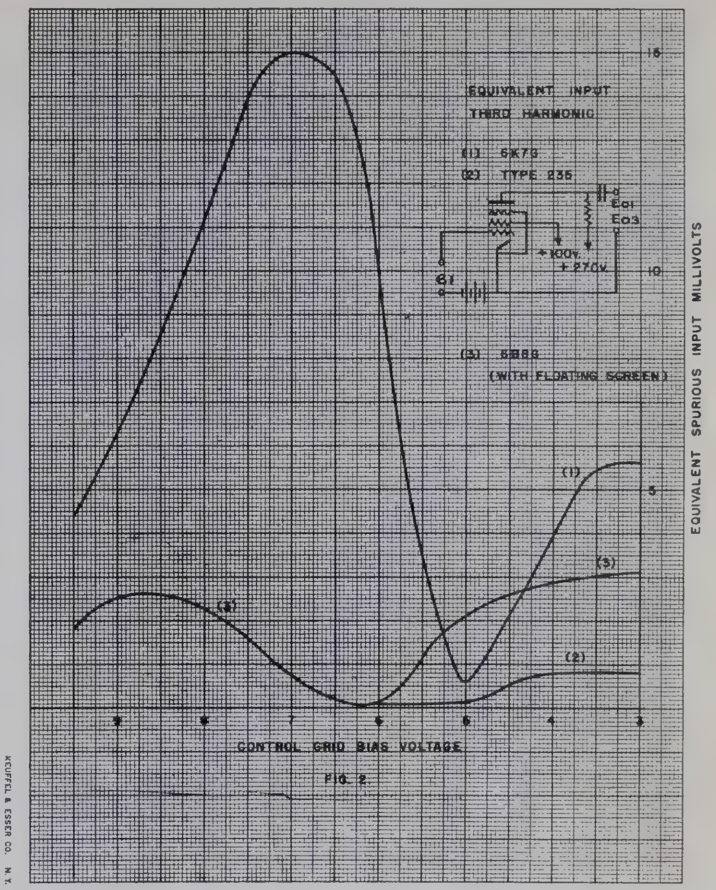

Fig. 2

TESTING RECEIVERS FOR CROSS-MODULATION

The Institute of Radio Engineers prescribes a standardized method(4) for studying the cross-modulation action in a receiver which is now in such general use as to required no detailed description here. By means of this method, the spurious modulation or cross talk which develops on the carrier of one signal due to the presence of another signal as a result of cross-modulation is determined, but the data so obtained do not permit of a direct interpretation with respect to the development of spurious or "phantom" signals. Through the equivalent spurious input concept suggested by this and the previous section of this discussion, a laboratory technique is indicated which has in practise proven to be exceedingly useful.

This method in common with the standardized two signal cross talk test of I.R.E. requires that two signal generators be connected to the receiver, usually through dummy antennae having twice the impedance of the standard dummy. The frequency of one generator is set at any desired value. That of the other is set at some value far enough removed from the first to avoid interference through insufficient receiver selectivity. In practice, the difference in carrier frequencies is chosen to be 50 kc not only because of receiver characteristics but because this frequency separation is common in the frequency assignment practices of the F.C.C. as they concern frequency assignments is any limited geographical area. For example, if one generator is set at 800 kc, the other would be 850 kc. It is possible then for two spurious signals to be produced, one falling at [2(800)−850]=750 kc, and the other at [2(850)−800]=900 kc. If either or both of the generator signals are modulated, the spurious signal will also be modulated.

In testing a receiver, only one of the two signals is modulated. Suppose that the modulated signal is the one of higher frequency. In the example cited this would be $e_2=Q(1+m \cos at) \cos qt$ where $q/2\pi=850$ kc. A spurious signal would be produced having the carrier frequency $(2q-p)/2\pi=900$ kc where $p/2\pi=800$ kc. It is:

$$\tfrac{3}{4}\, b_3PQ^2(1+2m \cos at) \cos (2q-p)t$$

The spurious signal at frequency $(2q-p)/2\pi=900$ kc is modulated, primarily at the modulation frequency $(a/2\pi)$ at the higher frequency signal with twice the original percentage modulation.

A spurious signal is also produced having the carrier frequency $(2p-q)/2\pi=800$ kc. It is

$$\tfrac{3}{4}b_3P^2Q(1+m\cos at \cos (2p-q)t,$$

carrying the same modulation frequency and percentage modulation as those of the original modulated signal.

The magnitude of (P) and (Q) on the tube grid will depend upon the selectivity and gain of the r-f circuits ahead of the tube. If the shape of the response curve for such circuit or circuits is symmetrical, and the antenna input magnitudes for the two signals are the same, the resulting spurious signals will be equal to each other in carrier magnitude. However, in this case, the one of higher frequency $(2q-p)/2\pi=900$ kc will create the most audio output signal after detection. Inasmuch as the former $(2p-q)/2\pi$ signal has the same percentage modulation as that of the original modulated signal, it is the most useful for receiver testing purposes.

In practice, the two generator signals are set at the same value, say two volts. The receiver is tuned to the lower of the two spurious signal frequencies. The audio output voltage obtained from this spurious signal is noted. Then the frequency of the modulated generator is changed until it is equal to the frequency for which the receiver has been adjusted, i.e., the lower spurious signal frequency. The output voltage of the generator is adjusted until the previously observed spurious signal audio output is obtained, all adjustments of the receiver being, of course, unchanged. The input voltage thus obtained is the *Equivalent Spurious Input* for the condition being studied. Its magnitude is approximately proportional to (P^2Q) where (P) and (Q) are the magnitudes of the lower and higher source frequencies respectively. This approximation obtains quite closely in practice, the equivalent spurious input being proportional to the square of the lower or un-modulated undesired signal at the first grid.

In making observations of this kind, several precautions must be observed:

1. The two signal sources must be free of second harmonics.

2. The test frequencies must be so chosen that spurious responses which can originate in the translator tube will not interfere with the observations. This latter requirement means, for example, that neither of the test frequencies should be at or near the second harmonic of the frequency of operation of the intermediate amplifier.

3. The grid bias on the r-f tube must be kept constant throughout any one set of observations.

4. The equivalent spurious input thus found is significant only for the particular values of test input used. These are, of course, half the indicated output of the generators where the dummy antennae have twice the standard impedance.

Although the determination of equivalent spurious input as outlined above does not obviate the need for studying cross-modulation by the conventional Two Signal Cross Talk method, it does give valuable practical information not otherwise readily deduced. It explains many of the "ghost" signals and, indeed, may account for some which are ascribed to "external cross-modulation." By expressing the spurious response in terms of an equivalent real signal, its nuisance value is at once evaluated. Anything which the designer succeeds in doing towards reducing the equivalent spurious input will also improve the cross modulation characteristic of the receiver. By working with the equivalent spurious input, the designer can quickly and accurately determine the effectiveness of any change which he may make in the hope of improving the condition.

Some typical observations of this kind are shown in Fig. 3.

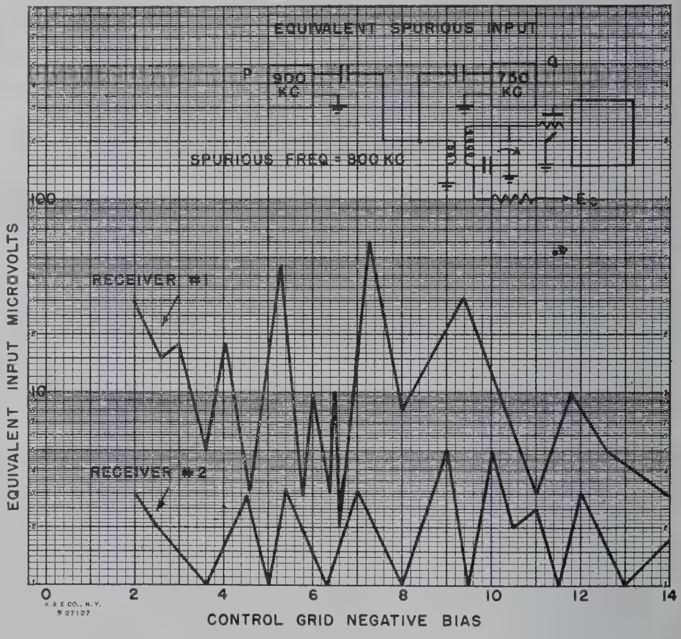

FIG. 3.

IMPROVING SPURIOUS RESPONSE THROUGH REDUCING AMPLIFICATION AHEAD OF FIRST TUBE

It is obvious that if the selectivity of the transmission system ahead of the first tube is increased without changing the resonant amplification, the equivalent spurious input signal will be reduced. A relatively large improvement can be obtained in this manner, because the spurious signal is proportional to the product formed by the square of one undesired signal and the first power of the other. However, in attempting to improve conditions through increased selectivity, the experimenter must be careful that he does not increase the resonant voltage amplification between the antenna and the first tube.

If the shape of the frequency-transmission curve ahead of the first tube is not changed but the voltage ratio for all frequencies is divided by a common factor, great improvement results. For instance, if this factor is m the equivalent spurious input signal will be reduced by the factor $(1/m^2)$, for the same magnitudes and frequencies of undesired signals.

For example, if (A_p) is the antenna to grid voltage ratio for the (P_1) signal at the antenna and (A_q) and (Q_1) are similar quantities for the other undesired signal, the equivalent spurious input at the antenna is

$$e' = \frac{kP_1{}^2A^2{}_pQ_1A_q}{A_r}$$

where (A_r) is the antenna to grid voltage ratio at resonance. If (A_p), (A_q) and (A_r) are all divided by the same factor (m), the expression becomes

$$e'_m = \frac{kP_1^2A^2{}_p\,Q_1A_q}{m^2A_r}$$

Most broadcast receivers to-day employ only one tuned circuit between the antenna and the first tube grid. The designer may find it possible to improve the selectivity of this circuit by employing component parts of higher quality. If greater selectivity is obtained by using a higher "Q" coil, the transformer gain will be increased for the same coupling coefficient, thus largely nullifying the hoped for benefit with regard to equivalent spurious input. If the coupling is then reduced until the antenna circuit gain is the same as before, the equivalent spurious input will be reduced but the signal to noise ratio for the receiver may suffer.

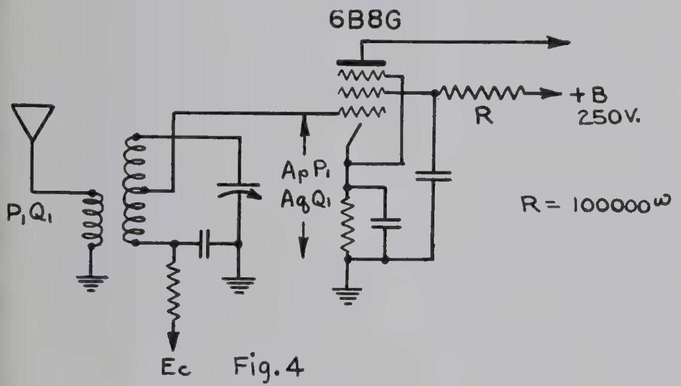

Fig. 4

An interesting compromise solution to this problem is illustrated by Fig. 4 where the first tube grid is shown connected to a tap on the secondary coil. The amplification from antenna to grid is reduced approximately by the ratio of the number of turns from grid to ground to the total number of turns. The thermal agitation noise presented to the tube grid is also reduced in the same ratio. Therefore, the ratio of signal to thermal agitation noise is the same as though the tube were connected across the condenser. The equivalent grid input tube noise, however, is relatively greater as compared to the signal, and some decrease in signal to noise ratio at the antenna results. Because, however, of the fact that the thermal agitation noise is several times greater than the tube noise when the tube is properly operated, the grid may be tapped down as much as half way before the overall signal to noise ratio suffers appreciably.

By using the 6B8G with self-regulating screen as the r-f amplifier, and with control grid connected to a half-voltage tap on antenna transformer secondary, a receiver may be designed to give distinctly exceptional performance with respect to cross-modulation and spurious signals. However, there is a real need for an r-f amplifier tube of more remote cut-off characteristic than the 6B8G and greater freedom from the generation of the spurious signals here discussed.

NOTES ON TRANSLATOR ACTION

With respect to cross-modulation, the analogy between the translator and the r-f amplifier is quite complete. The conversion conductance of the translator is analogous to the mututal conductance of the r-f tube. If the conversion conductance is related to control grid bias in a non-linear manner, cross-modulation can be produced by an unwanted modulated signal.

With respect to the generation of spurious signals, the translator possesses properties peculiar to itself. The phenomenon of image response may be thought of as a spurious one since it is unwanted, although it has the same characteristics as the desired response. The desired response generally has a frequency equal to the difference between that of the local oscillator and the desired frequency. The image signal is produced by an unwanted signal whose frequency is higher than that of the oscillator by the intermediate frequency. The magnitude of this image signal bears the same relation to the incoming unwanted signal voltage as does the desired intermediate signal to the desired incoming signal. Thus, the image signal can be reduced in magnitude relative to the desired one only by increased discrimination against the unwanted incoming signal.

The origin of all other spurious signals and cross-modulation can be determined by mathematical analysis similar to that referred to for the case of the r-f amplifier. Three incoming voltages, the desired signal, the undesired one and the local oscillator must be assumed, and the expansion must be carried through the fifth order term to show all of the most important effects.

The most important spurious signals are those whose frequencies fall near the frequency of the signal from which they are derived. For a receiver using an intermediate frequency such that twice its value falls within the desired reception band, spurious signals of the (2q–p) type are the most important. In this case, (P cos pt) is assumed to be the local oscillator voltage and [Q(1+m cos at) cos qt] is the interfering signal. The spurious signal is

$$e' = \tfrac{3}{4}b_3PQ^2(1+2m\cos at)\cos(2q-p)t$$

which is expression (2) for the r-f amplifier case.

If $(2q-p)/2\pi$ is equal to the intermediate frequency the spurious signal will be passed on to the second detector. For example let $q/2\pi = 900$ kc, and $s/2\pi = 465$ kc, where $(s/2\pi)$ is the intermediate amplifier resonant frequency. Then for the spurious signal (e′) to be received,

$2[900-(p/2\pi)] = 465$ kc or,
$p/2\pi = 1335$ kc.

When the oscillator frequency is 1335 kc, the r-f circuits of the receiver will be tuned to (1335–465) = 870 kc. The spurious signal, therefore, appears to be a real one having a carrier frequency of 870 kc. It can be measured in terms of its equivalent input in the manner described for spurious signals originating in an r-f amplifier. Spurious signals of this type are usually important for a range of 50 kc. above and below a frequency equal to the second harmonic of the intermediate frequency. Their magnitudes are dependent upon the control grid bias voltage and the square of the magnitude of the unwanted signal at that grid.

This same type of spurious response is responsible for the troublesome so-called second harmonic "tweet." It occurs when the receiver is being tuned to a signal whose carrier frequency is twice the intermediate frequency. In this case, regarding (q) as the desired signal, $2q-p=s=p-q$.

The undesired and desired effects are present at the same time and

$$2p=3q$$
$$q=2s$$
$$p=3s$$

If the local oscillator frequency is changed slightly, (p) becomes $(p+\Delta p)$ and $(p-q)$ becomes $(p+\Delta p-q)$. Also $(2q-p)$ becomes $[2q-(p+\Delta p)]=s-\Delta p$ and $(p+\Delta p-q)=s+\Delta p$

The two new frequencies differ by $(2\Delta p)$. If this difference is audible after detection, a whistle or tweet is heard. The pitch of the whistle will change at twice the rate of change of the local oscillator frequency.

Another important group of spurious signals are often found in a frequency band near that of the third harmonic of the intermediate frequency. This is a fifth order effect by which the third harmonic of the signal is created within the translator and caused to beat with the second harmonic of the local oscillator. The apparent incoming frequency (f) of this spurious signal is related to the (q) signal frequency by

$$2\pi f=3/2\ (q-s)$$

If $(s=\frac{1}{3}q)$, the spurious signal frequency is the same as that of the incoming signal and slight deviations from this produce an audible whistle after detection.

ACKNOWLEDGMENT

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(3) F. B. Llewellyn, "Operation of Thermionic Vacuum Tube Circuits, Bell System Tech. Journal, Vol. 5, p. 433.

(4) 1933 Report of the Standards Committee of the Institute of Radio Engineers, p. 96.

Report LB-380, R.C.A. License Division, "Selectivity Characteristics of 1930-36 Receivers and Analysis of Various Types of Interference."

Preliminary Discussion with the Underwriter's Laboratories on Television Receivers

By E. T. Dickey, RCA Manufacturing Co.

On December 3, 1937 a meeting was held at the Underwriters' Laboratories in New York City, between representatives of RMA and representatives of the Underwriters' Laboratories to discuss informally the safety provisions and electrical tests which the Underwriters might require in the case of television receivers.

During the course of the discussion it was pointed out that while it was not planned to offer television receivers for sale in the immediate future, the engineers who would eventually develop and build television receivers were in need of some general indications of the safety factors and the provisions against shock hazard which the Underwriters Laboratories might require in such equipment.

The details of the matter were discussed by reviewing specific pertinent paragraphs of the present Underwriters' requirements with respect to radio receivers and by asking for opinions as to the possible changes in these requirements which the Underwriters would feel were necessary in their application to television equipment. The results of this discussion are given below, classified under the paragraph numbers of the present requirements.

Paragraph 28 — Permissible Openings in Power Transformer Casings.

It was brought out that transformer secondary potentials would be likely to be around 5000 volts. It was indicated that the secondary leads of such transformers probably should therefore be protected by porcelain bushings. Since it was assumed that transformers would probably be likely to burn out under short-circuit conditions, it was indicated that open holes in power transformer casings would be undesirable.

As a result of a question raised by one of the RMA representatives it was agreed that only one such bushing would be needed if one side of the high voltage secondary was grounded to the case.

Paragraph 31—High Voltage Wiring Requirements.

The Underwriters were asked what types of good quality wire were available and approved by them for use at high secondary voltages. The attention of the RMA representatives was, therefore, called to the types of conductors approved for gas tube sign and oil burner ignition uses. These are designated as GTO-5, GTO-10 and GTO-15, which are approved for 5,000, 10,000 and 15,000 volts respectively. The conductor sizes of 14, 12 and 10 A.W.G. are available in all of these types of wire. For high-tension, direct-current circuits, it was suggested that Type GTO-5 cable might be found to be acceptable for 6000 volts, but that Type GTO-10 would probably be needed for 7000 volts. With reference to power cords for television receivers, the Underwriters stated that No. 18 gauge power cord wire had recently been approved for inputs up to 5 amperes.

Paragraph 34—Chassis Voltage to Ground.

It was pointed out that if in a television receiver the proper connection of the ground lead is omitted the chassis might possibly assume a voltage of 3,000 with respect to ground as a result of secondary leakage currents. The Underwriters at first suggested the use of a three prong power plug to provide a ground connection through the third terminal. The obvious service and sales difficulties of such an arrangement were emphasized and it was finally agreed that it would be satisfactory if the chassis were tied to each side of the power line through resistors of 100,000 ohms or more. This would of course prevent a leakage voltage from building up on the chassis and in addition would limit to a permissibly low value the current to which the user of the receiver might be exposed by contact with a control shaft connected to the chassis. It was agreed that a connector for grounding the chassis could be brought outside the instrument cabinet if necessary.

Paragraph 37—Interlock on Cabinet.

It was indicated that an interlock which would effectively turn off the power supply on removal of the rear of the cabinet would be required by the Underwriters. One suggested arrangement was the possible use of two switches in association with the back or cover, both of which would assume the "off" position if the back or cover were removed. Another suggested arrangement was the provision of a cord connector on the back which would disengage male pins or blades when the back is removed—such a connector would be required to be non-interchangeable with connectors for general use.

It was pointed out that the back cover should be reasonably thick and that where there was likelihood that it could be bent outwards so as to allow access to live parts without breaking a single interlock located at one side, that an interlock on each side might be necessary.

Protection of the user against possible breaking of the Kinescope was discussed at length and it was pointed out that a plate glass or shatter-proof glass protector would be provided at the top of the cabinet over the face of the tube. This, in addition to the protection provided by the cabinet was considered adequate protection for the user.

Paragraph 39—Ventilating Holes in Cabinet.

With respect to the guarding of ventilating holes, it was pointed out that special precautions will be necessary were extra-high potentials are involved, such as at kinescope and rectifier-tube terminals. The Underwriters stated that it would be necessary for them to have specific examples of proposed constructions before them in order to judge the adequacy of protection afforded against the hazards of accidental contact through ventilating openings.

The Underwriters raised the question of possible use of acorn tubes and indicated that they would probably

Continued on page 17

Preferred Numbers and the Radio Industry

By Arthur Van Dyck, Radio Corp. of America

Explanations of the "Preferred Numbers" system, descriptions of the advantages, and listing of various past applications, have been published in other journals and thus need no repetition here. So little utilization of the principle has occurred so far in the radio industry, however, that this article has been prepared to point out some of the possibilities of the system, by the example of what has been accomplished in fields closely associated with radio field and, more specifically by the example of the application of preferred numbers that has been made by one company in a similar field.

It will be remembered that it is basic to the principle of preferred numbers that in any work of designing there are many cases in which the designer has latitude in choice of dimensions ratings or other constants so that his decision with respect to the numerical values are quite arbitrary within certain and frequently extremely wide limits. It will be obvious that if certain numerical values are universally accepted as "preferred" and are used whenever they meet the requirements at least as well as any other arbitrary choices, the consequent identicality of choices will almost inevitably later result in simplifications and usefulness which may, indeed, not even have been in mind in the original making of the choice. Thus, such advantages and savings as the following may be expected to result from the consistent and general use of preferred numbers:

1. Component materials or parts can be made with a minimum number of standard sizes, ratings or other characteristics so chosen to meet all of the rational needs of their users and especially to meet the needs of those who, themselves, have adopted preferred numbers in connection with their products.

2. Measuring equipment and production machinery can be simplified and cheapened, because it becomes necessary to provide only for a definite, limited number of preferred values of dimensions or other characteristics.

3. Odd sizes, manufactured through ignorance of real requirements or to meet the supposed, but really illogical, needs of a customer or industry, can be eliminated.

4. Operations become simpler for both producers and users, because calculation, manufacture, commerce, catalogs, price lists, and human memory deal only with certain easily memorized and widely used numerals.

A strikingly effective example of the use of preferred numbers and one which has been in use for seventy years, is the Brown and Sharpe wire gauge. The basis of its size variations is that of a geometric progression giving each increasing size a diameter greater than the preceding one by a constant percentage. It is possible that the popularity of this gauge is in large measure due to the utility inherent in the preferred number idea of which it has been for so many years so successful an exponent. The system is nothing more than an intelligent method of selecting sizes so as to afford the greatest utility and convenience, and to cover the full range with the minimum number of sizes.

For about fifteen years past, various organizations in this country, interested in industrial standardization, have been working to develop a system of preferred numbers which would be suited to effective utilization by all American industry. Under the procedure of the American Standards Association a system has now been developed which is thought suitable for wide application and which, in part, is given in the table below:

BASIC PEFERRED NUMBERS—DECIMAL SERIES
(10 to 100)

5 Series 60% Steps	10 Series 25% Steps	20 Series 12% Steps	40 Series 6% Steps
10	10	10	10
			10.6
		11.2	11.2
			11.8
	12.5	12.5	12.5
			13.2
		14	14
			15
16	16	16	16
			17
		18	18
			19
	20	20	20
			21.2
		22.4	22.4
			23.6
25	25	25	25
			26.5
		28	28
			30
	31.5	31.5	31.5
			33.5
		35.5	35.5
			37.5
40	40	40	40
			42.5
		45	45
			47.5
	50	50	50
			53
		56	56
			60
63	63	63	63
			67
		71	71
			75
	80	80	80
			85
		90	90
			95

Preferred numbers below 10 are formed by dividing the numbers between 10 and 100 by 10, 100, etc.

Preferred numbers above 100 are correspondingly formed by multiplying the numbers between 10 and 100 by 10, 100 etc.

Percentage steps in headings are approximate averages.

While it is by no means important to the application of preferred numbers to the specific problems of industry it may be of interest to the engineer to note that any series of preferred numbers should comprise a geometric series: i.e., each succeeding number should be a fixed ratio with respect to the preceeding number and it thus follows that the multiplying factor there involved is some root of the ratio of the first and last numbers in the series. Thus, in the A.S.A. system of preferred numbers which is finding wide application in American Industry, only one decade of which is shown above, the range of numbers is between 10 and 100 and in this range four series have been formulated; the "coarsest" being the 5 series, in which there are five preferred numbers between 10 and including 100 and, of course, each succeeding number is equal to the product of the preceeding number and the fifth root of ten. Similarly formed series of increasing "finess" have been formulated and are given in the table up to the 40 series which is doubtless as "fine" as any series of preferred numbers need be for the purposes of industry and certainly as fine as any series need be for ready application to the radio industry.

To the radio engineer it will be of special interest to note that notwithstanding the fact that the mathematical relations basic to the Brown and Sharpe system of wire gauges are based on the doubling of the diameter of the wire for each increase of six sizes and hence each succeeding wire diameter is greater than the preceeding one by a ratio equal to the sixth root of two, the 20 series of the A.S.A. system of preferred numbers is substantially identical with the set of wire tables that every radio engineer has conveniently at hand. The especial importance of this lies in the fact that as the radio engineer finds increasingly frequent application for the A.S.A. system of preferred numbers to his product he need only refer to his ever present wire tables for the preferred values that will make his choice of constants quite consonant with that of all American industry.

Typical of this kind of industrial application of preferred numbers are the applications made by the Westinghouse Electric and Manufacturing Company to sizes of stock parts, raw materials stock sizes and the like. There follows a list of a number of application now in common use by that company; the preferred number series referred to are, of course, those given above:

"Preferred Numbers" Applications to W. E. & M. Co's Designs, Parts and Materials

DESIGN

SUBJECT	PREF NO.	SERIES
Fits and Tolerances—Ranges of shaft dias. on which shaft fits are based	10 & 20	Decimal
Ampere Ratings, Grid glow tubes .015—.1—.64—2.5—4—10—25	5	"
Armature Bores	40	"
Armature Outside Diameter	40	"
Stator Punchings Outside Diameter	40	"
Insulation Washers Inside Diameter	20 & 40	"
Outside Diameter	40	"
Gear Ratios	20	"
Mounting Dimensions of Electric Motors N.E.M.A. (Dimensions A—E—D—O)	20	Fraction

PARTS

SUBJECT	PREF. NO.	SERIES
Bolts:		
Hex. Hd.—Diameters	10 & 20	Fraction
Hex. Hd. —Lengths	10–20 40	"
Square Hd.—Diameters	10 & 20	"
Square Hd.—Lengths	10 20–40	"
Cap Screws—Lengths	10–20 40	"
Drive Screws—Lengths	10	"
Machine Screws—Lengths	10–20–40	"
Headless Set Screw—Lengths	10	"
Safety Set Screw—Diameters	10	'
—Lengths	10–20–40	"
Sq. Hd. Set Screw—Diameters	10	"
Sq. Hd. Set Screws—Lengths	10–20–40	"
Wood Screws—Lengths	10–20	"
Spacer, Steel—Diameter and Lengths	10 & 20	"
Stud, Steel—Diameter	10	"
—Lengths	20 & 40	"
Washers, Plain	10 & 20	"

RAW MATERIALS

SUBJECT	PREF. NO.	SERIES
Ins. Tube Mandrels—Diameters	20–40–80	Fraction
Micarta Plate Tks.	10–20	"
Micarta Angles, Channels, Bars	10–20	"
Steel Bar:		
CR—Round	10–20–40	"
CR—Rect. Thickness	10–20	"
HR—Rect. Thickness	10–20	"
HR—Rect. Width	10–20–40	"

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Preliminary Discussion with the Underwriter's Laboratories on Television Receivers

Continued from page 15

consider such tubes, if used, as non-serviceable from the customer's standpoint.

Paragraph 48—Glass Fuse Approved for 5 Amperes at 125 Volts.

In response to inquiry as to whether any such fuse was approved by the Underwriters it was stated that it was **not** but that the limiting factor had been the requirement of 220 volt operation (At present the highest Underwriters listed fuse of this type is 3 amperes). It was stated that it would very likely be possible to approve such a fuse provided its use were definitely limited to 125 volt circuits. It was further indicated that the Underwriters' laboratory would be glad to make tests leading to approval of such fuses if they were submitted by fuse manufacturers.

Paragraph 68—Breakdown Test Voltages.

The breakdown test voltages for secondary wiring on radio receivers have long been set at three times the normal operating voltage. It was pointed out by the RMA representatives that such a requirement if applied to television receivers would lead to unnecessarily high test voltages. After considerable discussion the following was agreed to as a tentative requirement:

> Tests on capacitors to be 125% of normal maximum voltage.
>
> Tests on power transformer and secondary wiring, two times normal maximum voltage plus 1,000 volts.

In view of the difficulty of obtaining the values of high d-c voltage required for these tests the Underwriters indicated that they would probably make these tests with a-c voltage.

Tests on the chassis including the main r-f and i-f circuits, which it is assumed, would employ voltages of the same order as those employed in broadcast receivers, would be made under the 3 times normal voltage requirement now in effect.

Oscillator Stabilization for Mechanically Tuned Household Receivers

By A. G. Manke, General Electric Company

The importance of mechanical tuning in all entertainment type receivers has resulted in the concentration of attention on the stabilization of oscillators and I. F. transformers against drift due to humidity, temperature, line voltage and signal input.

Mechanically tuned receivers of recent design and in the higher price ranges have, in general, been equipped with automatic frequency control. This has of course reduced the accuracy required of the mechanical system and similarly reduced the need for precautions against oscillator drift. Since mechanical or pushbutton tuning has now been extended to practically all receivers, in many of which economic considerations preclude the use of automatic frequency control, it has become necessary to find ways of stabilizing the oscillator against drift at a minimum cost. In receivers not equipped with automatic frequency control the allowable drift due to temperature and humidity varies with the price class of the receiver, the accuracy of the mechanical system and the ACA of the I.F. amplifier.

In receivers in which automatic frequency control and greater mechanical accuracy of the tuning system is not prohibited by considerations of cost, there is a tendency toward omitting automatic frequency control. This is doubtless due in part to the simplification of the receiver which results from the omission of automatic frequency control and also due to the recognition of the disadvantages of automatic frequency control. No doubt the characteristic of automatic frequency control most troublesome to the listener is the tendency of the receiver to select an adjacent channel station during periods of fading of the received signal or during periods of exceptional signal strength on the adjacent channel. An exceptional case of strong adjacent channel stations was recently observed in one of the large metropolitan residential districts. In this case the signal strength of a prominent local station during the evening was less than either of the adjacent channel stations which were four and six hundred miles distant from the local station. Such conditions occur largely where local stations have low field strengths over certain areas of the city. Then too, there are many locations where distant stations are received regularly and several pushbuttons are set up on stations which are more than one hundred miles distant. In these cases fading is inevitably of serious importance and the tendency for the receiver equipped with automatic frequency control frequently to tune in an adjacent channel station becomes a serious problem. The drift in oscillator, I.F. system, or inaccuracy of the mechanical tuning system aggravate this condition.

With these considerations in mind it is evident that from the operational standpoint there are some real advantages to be gained in the design of a receiver which will provide pushbutton tuning without the difficulties mentioned above. Where the drift problem and the mechanical tuning problem have been reasonably well solved, the question of retaining automatic frequency control is one which is distinctly debatable and is determined by both electrical and mechanical considerations. The mechanical problems here involved will not be considered in this paper as they are of so fundamentally different a nature from those associated with the electrical stabilization of the receiver here discussed.

The reduction of frequency drift requires consideration of the effects of variation of temperature, humidity, line voltage and signal input on the receiver. When considering the effect of temperature it is probably sufficient to work within an ambient temperature rise of 25° C for household receivers. In testing a typical receiver in which no particular precautions had been taken to avoid oscillator drift it was found that due to this temperature change alone, the drift at 580 KC was 3.5 KC and at 1250 KC the total drift was 8.50 KC., the temperature increase producing a negative frequency drift throughout the band. This chassis when tested under the condition of 90% relative humidity showed a drift of 7.0 KC at 580 KC and a drift of 15.0 KC at 1250 KC for the same temperature rise, thus indicating that if temperature effects are corrected, a large portion of the oscillator drift will disappear. It is therefore desirable to correct for temperature effects before considering humidity.

In analyzing the contribution of the various components to the temperature drift occurring at the high frequency end of the broadcast band and neglecting drift due to the initial "warm-up" of oscillator tube, it was found that about 40% of the drift could be eliminated by substituting a trimmer employing air dielectric in place of mica as the dielectric, by the use of aceramic oscillator tube socket and by changing the construction of the oscillator coil. This latter comprised removal of the cambric used to insulate primary from secondary and rewinding the primary adjacent to the low potential end of the solenoidal secondary. Additionally, the replacement of the bakelite grid condenser by a sprayed mica type of condenser accounted for a further reduction in drift of 5%.

Another component which was found to have an appreciable temperature coefficient was the adjustable padding condenser. The effect of the padder at the high frequency end of the band was, of course, negligible; however, it was a major item at the low frequency end of the band.

To determine what portion of the remaining drift was due to the oscillator coil this component was removed from the chassis and placed in a separate box so the heat effects due to the coil alone could be determined. It was found that the oscillator coil accounted for slightly less than half of the remaining 55% temperature drift at 1250 KC. The remainder of the temperature drift was then due to the treated bakelite switch wafer, the bakelite insulated gang condenser, the tube base, and the wiring. As gang condensers are now commercially available equipped with ceramic insulation the bakelite insulated gang condenser was replaced with one having ceramic insulation. This change reduced the remaining temperature drift to approximately 5% which is apparently due to the bakelite switch wafer, wiring, bakelite insulation in oscillator tube base, and ceramic insulation of trimmer condenser, tube socket and gang condenser.

Since no simple expedient which is readily adaptable to production receivers and which will appreciably reduce the remaining temperature drift is known, it seemed advisable to conduct tests with commercially available condensers of negative temperature coefficient of the ceramic type and also with bi-metal temperature compensating condensers mounted on ceramic bases. The temperature compensation obtainable from either of these condensers proved to be adequate to compensate for the remaining drift due to temperature. With these modifications made in this receiver, the temperature drift near the low-frequency end of the broadcast band (580 KC) was 1900 cycles and near the high frequency end (1250 KC) of the band it was 2600 cycles for a rise of 250 in the ambient temperature. The total capacity across the oscillator coil at each of these frequencies was approximately 240 and 100 uuf respectively. The capacity compensation required to correct this drift can be calculated since the capacity in the circuit is proportional to the reciprocal of the frequency squared:

$$\omega^2 = \frac{1}{LC}$$

For frequencies near 1500 kilocycles the padding condenser can be neglected and the capacity corresponding to a small frequency change can be obtained by differentiation* which gives:

$$\frac{dc}{c} = \frac{2d\omega}{\omega}$$

$\triangle c$ = capacity increment
c = capacity of tuning condenser
ω = oscillator frequency
$d\omega$ = frequency drift
I.F. Frequency = 465 KC

Then for a drift of 2600 cycles at 1250 KC:

$$dc = -\frac{2d\omega c}{\omega}$$

$$= -\frac{2 \times 2.6}{1715} \times 100 = \frac{520}{1715} = -.300\ \mu\mu f$$

To obtain a decrease in capacity of .300 $\mu\mu$f with a condenser having a negative temperature coefficient of capacitance of 6.5×10^{-4} $\mu\mu$f per degree, C, over a temperature range of 25° C. will require a capacitor of

$$\frac{.300}{6.5 \times 10^{-4} \times 25} = 18.5\ \mu\mu f$$

A fixed compensating condenser of this value can be shunted across the oscillator trimmer and still leave ample trimming capacity in the variable trimmer condenser when tuning the usual range covered by the broadcast band.

The capacity compensation required at the low frequency end of the band can be obtained by shunting the negative-temperature-coefficient-condenser across the padding condenser. This then compensates for the change of inductance of the oscillator coil and also for whatever temperature drift occurs in the padding condenser. When a sprayed mica condenser is used as a fixed padder the compensation required in this portion of the circuit is small as compared with that required where the best treated type of variable padder is used. Near the low frequency end of the broadcast band the capacity in the padding condenser is essentially equal to that of the tuning condenser for the I.F. frequency most commonly used in household receivers. Therefore, the value required to compensate for a given per cent drift will be approximately twice the value calculated from the formula given above.

A test on several chassis equipped with compensating condensers as calculated above showed that the low frequency portion of the broadcast band could be compensated to approximately plus or minus 200 cycles; however, at the high frequency end the error due to variations in components and variation in coefficient of the compensating condensers could not be compensated for to less than plus or minus 400 cycles. However, any individual chassis could easily be compensated to plus or minus 100 cycles throughout the band.

With these adjustments for temperature compensation, these chassis were tested in a humidity chamber at 90% relative humidity. Without further modification the average drift encountered at 580 KC increased to 500 cycles and at 1250 KC the average drift increased to 2400 cycles after 24 hours.

The oscillator coil was then impregnated in wax and carefully flash-dipped to reduce the effects of moisture on the coil form. This expedient resulted in only a slight reduction in drift at 580 KC but was very effective at 1250 KC where the drift was reduced to less than one-half its former value. An investigation of the remaining drift due to humidity showed that further modification of chassis components to reduce drift was not warranted because of the effect of moisture on commercially available compensating condensers.

Tests of the oscillator drift resulting from variations in line voltage or signal input at 1000 KC showed these frequency drifts to be negligible when a separate screen grid type oscillator tube was used. Where, however, the pentagrid converter was used, the frequency drift resulting from the variation of line voltage or signal input was sufficient to necessitate a considerable rearrangement of the voltage supply circuit. Thus instead of obtaining the screen and oscillator plate voltages from the 100 volt and 180 volt supplies provided on the bleeder resistor it was found necessary to obtain these voltages by means of separate voltage dropping resistors feeding from the highest available D.C. voltage in the power pack. The effective regulation of D.C. voltage supplied to the plate and screen was thereby improved to such an extent that line voltage variations of plus or minus 12 volts caused a negligible frequency shift. Additionally this arrangement served also to reduce the frequency shift due to variation of input signals to not more than 0.5 KC under such conditions of input signal variation as commonly result from fading, the differences between day and night transmission, the sharing of broadcasting channels and the like.

APPENDIX

Ordinarily

$$\omega^2 = \frac{1}{LC}$$

However, since the actual oscillator circuit consists principally of two capacities and an inductance arranged as shown below

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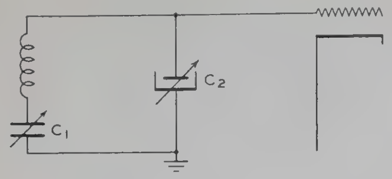
*—See appendix covering derivation of formula for readily computing equivalent inductance or capacity increment of tuning condenser or padder for small frequency drift.



we have

$$\omega^2=\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right) \qquad (1)$$

For small changes in the circuit elements, we can take differentials of both sides, and write

$$2\omega d\omega=\frac{d\ (\omega^2)}{dC_1}dC_1+\frac{d\ (\omega^2)}{aC_2}dC_2+\frac{d\ (\omega^2)dL}{aL}$$

$$=-\frac{1}{LC_1{}^2}dC_1-\frac{1}{LC_2{}^2}dC_2-\frac{1}{L^2}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)dL$$

$$=-\frac{1}{LC_1}\left(\frac{dC_1}{C_1}\right)-\frac{1}{LC_2}\left(\frac{dC_2}{C_2}\right)-\frac{1}{L^2}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)\ dL \qquad (2)$$

Next let

$$A=\frac{dC_1}{C_1} \text{ and } B=\frac{dC_2}{C_2}$$

Then

$$=\frac{1}{LC_1}\left(\frac{dC_1}{C_1}\right)-\frac{1}{LC_2}\left(\frac{dC_2}{C_2}\right)=-\frac{A}{LC_1}-\frac{B}{LC_2}=$$

$$-\frac{1}{L}\left(\frac{C_2A+C_1B}{C_1\ C_2}\right)$$

$$=-\frac{1}{L}\left(\frac{C_1+C_2}{C_1\ C_2}\right)\left(\frac{C_2A+C_1B}{C_1+C_2}\right)=$$

$$-\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)\left(\frac{C_2A+C_1B}{C_1+C_2}\right)$$

$$=-\frac{1}{L}\left(\frac{1}{C_1}+\frac{1}{C_2}\right)\left[\frac{C_2\frac{dC_1}{C_1}+C_1\frac{dC_2}{C_2}}{C_1+C_2}\right] \qquad (3)$$

As a consequence of equations (1) and (3), equation (2) may be written:

$$2\omega d\omega=-\omega^2\left\{\frac{C_2\frac{dC_1}{C1}+C_1\frac{dC_2}{C_2}}{C_1+C_2}+\frac{dL}{L}\right\} \qquad (4)$$

Then dividing thru the equation by $2\omega^2$, we get

$$\frac{d\omega}{\omega}=-\frac{1}{2}\left\{\frac{C_2\frac{dC_1}{C_1}+C_1\frac{dC_2}{C_2}}{C_1+C_2}+\frac{dL}{L}\right\} \qquad (5)$$

Where L and C_1 are constant

$$\frac{d\omega}{\omega}=-\frac{1}{2}\left[\frac{C_1}{C_1+C_2}\ \frac{dC_2}{C_2}\right] \qquad (6)$$

$$\frac{dC_2}{C_2}=-2\frac{C_1+C_2}{C_1}\ \frac{d\omega}{\omega} \qquad (7)$$

$$dC_2=-2C_2\frac{d\omega}{\omega}\times\frac{C_1+C_2}{C_1} \qquad (8)$$

At the high frequency end of the band $\frac{C_1+C_2}{C_1}$ is small therefore

$$dC_2=-2\frac{d\omega}{\omega}\ C_2$$

To find the change in padder capacity for a small drift in oscillator frequency. In this case C_2 and L are constant then from equation 5 we can write

$$\frac{d\omega}{\omega}=-\frac{1}{2}\left[\frac{C_2}{C_1+C_2}\ \frac{dC_1}{C_1}\right] \qquad (9)$$

$$\frac{dC_1}{C_1}=-2\frac{C_1+C_2}{C_2}\ \frac{d\omega}{\omega} \qquad (10)$$

$$dC_1=-2\ C_1\frac{d\omega}{\omega}\ \frac{C_1+C_2}{C_2} \qquad (11)$$

For the above derivation I am indebted to Dr. Stanford Goldman of the Advanced Development Section.

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Video Frequencies

As is not unusual in the practical development of a new art such as television there appears to be some confusion as to nomenclature especially with reference to the significance of the term **"Video."** It appears pertinent, therefore, to point out that video frequencies are defined as those frequencies which result from the process of scanning.

Thus, at the television transmitter we have video frequencies generated at the scanning equipment and throughout the transmitter circuits up through the modulator. And in the receiver we again have video frequencies beyond the second detector. In brief, wherever in the television transmitting and receiving system the frequencies are the analogue of the audio frequencies of the sound transmitting-receiving system, it is common to refer to these as video frequencies.

A. F. Murray

Probable Test Equipment Requirements for Design and Tests of Domestic Television Receivers

By J. M. Brumbaugh, RCA Manufacturing Co, Inc.

In attempting at this time, to outline the methods, and requirements, as to equipment which will be adequate for the testing of domestic television receivers, one has a strong inclination, as a result of the recent history of the art, to keep his fingers crossed. However, in view of the presently crystallizing standards as to the general method of reproduction, channel width, picture and sound separation, scanning system, etc., and regardless of the form of synchronizing impulses and background control which may be used, certain general requirements as to test equipment have been developed and are here formulated.

The general theory and practice of cathode ray television systems have been treated in the various technical journals, and will therefore, not be reviewed here since it is assumed that the general principles have been clarified for the reader by these publications.

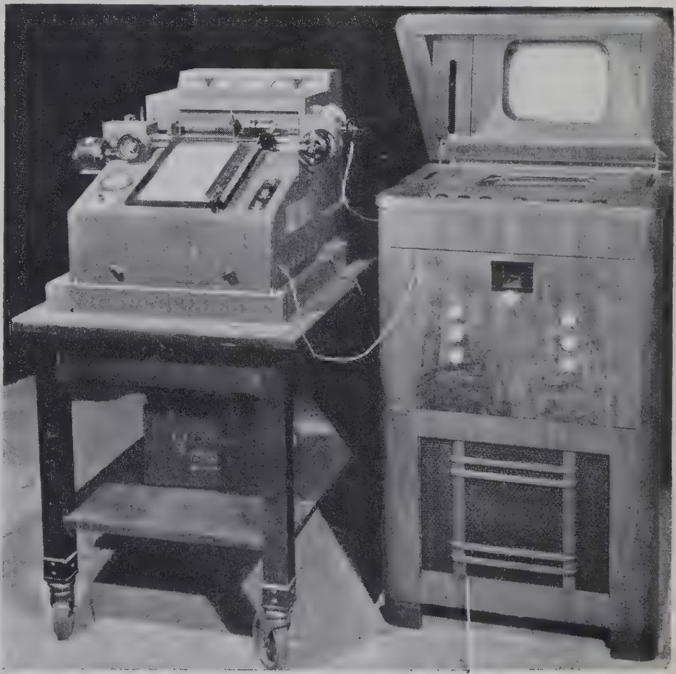
Many elements of the receivers, such as A.V.C. circuits, audio amplifiers, low-voltage power supplies, etc., are found to be quite familiar to the broadcast receiver engineer. Except for the probable increase in audio fidelity, made possible by the wider sound channel and improved audio design, these familiar elements here require no special consideration.

The video detector and amplifier, feeding the control grid of the Kinescope, must not only have a fairly flat frequency response from low audio to several megacycles, but must have a also constant time delay over this band in order that appreciable wave-form distortion due to phase shift between components may be avoided. Frequency or phase distortion anywhere in the system will, of course, be evident as a loss of detail, or by the presence of "ghost" images in the picture. Such difficulty in the television receiver as this may be localized most conveniently by means of so called "square-wave" tests. Starting at the output, square-wave impulses are fed into the video amplifier in such a way as to give a stationary pattern of lines, or segments of lines having uniform brightness and sharply defined ends on the Kinescope screen. If the amplifier satisfactorily passes both high and low frequency square waves, as shown by such a visual inspection as this its operation is satisfactory. Where the cause of poor detail is thus localized in the video amplifier, by square-wave checks on successive stages, it can be corrected by analysis of the circuit, at that point, for phase or amplitude distortion. Having obtained satisfactory operation in the video amplifier system, the i-f and r-f circuits must next be considered.

The separate i-f sound and picture channels will operate in the region of 10 megacycles, and will thus differ from broadcast i-f amplifiers in circuit constants and design, and in band-width ratio as defined by the quotient of the band width divided by mean frequency. Particularly is this true of the picture channel, which is considerably greater than in broadcast i-f circuits. The sound channel i-f is of course, wider than in broadcast receivers to allow for oscillator drift and is consequently of much broader audio band width. Although the circuit components are thus considerably different from their broadcast receiver counterparts, the design and alignment procedure, when carried on with proper test equipment, is substantially the same. Selectivity and alignment tests require an oscillograph on the detector output, along with a signal generator which will sweep through the i-f bands and which incorporates a calibrated marker oscillator for producing a frequency-reference hump on the response curve.

The alignment of the picture i-f is usually checked first for high frequency cut-off at the proper frequency, for band width, for flatness of response, and for overall gain. Since the band is several megacycles wide, it tends to have a double peak, which must be minimized by careful design.

The procedure for the sound i-f is similar. It should be noted, however, that in reception of carrier and one side band with partial suppression of the other side band, it is necessary to carefully maintain a certain frequency difference between the peak of the sound channel and a given point as conveniently expressed in percent of full gain, on the high-frequency cut-off of the picture channel. This is necessary since the entire signal, comprising picture and sound carriers, with their respective sidebands is tuned, by the operator, with reference to the sound channel only, and the location of the converted picture carrier on the picture i-f curve and therefore the picture fidelity, is thus dependent on this frequency interval between the two i-f channels. The carrier fre-



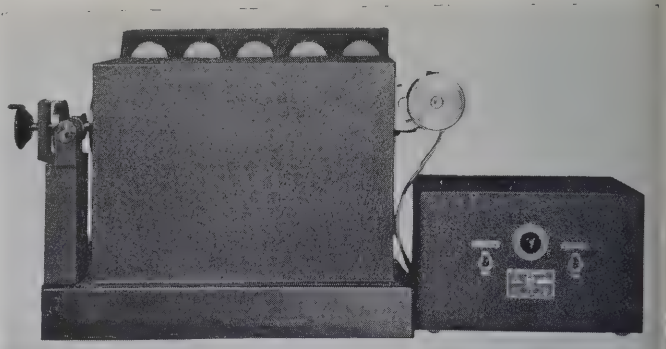
quencies can be carefully set by means of the marker oscillator on the video sweep signal generator.

The r-f and mixer circuits are analogous in principle to those of the broadcast receiver system, differing essentially because of the necessarily wide pass-band which includes both picture and sound carriers and sidebands with the consequent design problems as to rejection and selectivity and because of the fact that the mixer must feed two i-f channels. Proper over-all operation of the r-f system can probably be checked most simply by connecting an oscillograph to a special bridging circuit which will supply signal from both 2nd detectors and to the oscillograph sweeping an r-f signal over the entire r-f band. A double response curve will then appear on the screen, the two humps being essentially the characteristics of the two i-f channels placed side by side, provided that the r-f system is properly aligned. Placing the marker oscillator on the r-f generator at the frequency to which the receiver dial is set, alignment must then be so made that the marker hump will fall at the middle of the sound channel characteristic, and r-f circuits "trimmed" so that the overall form of the i-f characteristics will be maintained, i.e., flat r-f response over the pass band. These conditions must, of course, be met at various frequencies in the tuning range, and adequate sensitivity maintained.

Methods of overall sensitivity measurement should be fairly obvious from the foregoing. Certain tolerances will be necessary as to selectivity and rejection, and receivers should presumably be designed so that the service engineer will have little trouble with cross-modulation between picture and audio channels, images, etc., provided that he does a proper job of alignment when such servicing becomes necessary.

The synchronizing and blanking impulses, which control the Kinescope deflection circuits and cut off the electron beam during retrace, are a part of the video signal. The horizontal and vertical deflection-control function is "picked off" from the video signal at the 2nd detector output by means of amplitude and time-constant selector circuits. Adequate and fairly simple testing for the proper design and functioning of these circuits can probably be accomplished by tuning-in an actual signal and making oscillographic tests to see that proper magnitudes and separation of signals are obtained in the various receiver elements—the quantitative relations being determined by the particular system of transmission which is used. The same process should be useable in checking the design of the synchronizing and deflection oscillator circuits. The synchronizing impulses will be so arranged in the transmitted signal as to produce proper interlacing of the alternate scanning patterns, provided that the selector, synchronizing, and deflection circuits in the receiver are adjusted for proper inter-relationships—these relationships being observeable, for the most part, in terms of measurements on a calibrated oscillograph.

It is felt that, aside from such conventional tests as that of tube voltages, presence of hum, A.V.C. action, etc., the foregoing represents a sufficient outline of procedure for preliminary operation checks on design, or for analyzing the troubles which might be expected in most ordinary servicing of home receivers. It will be remembered that, aside from the assortment of test equipment which should be found in the broadcast receiver laboratory, or in the shop of a competent service engineer, mention has been made of three pieces of special equipment. These are:



(1) "A Square-Wave Generator".
(2) A Video and Radio-Sweep Signal Generator, i. e. "Universal Sweep Oscillator".
(3) A specially Calibrated Cathode Ray Oscillograph.

The performance requirements for these units appear to be approximately as follows:

(1) "Square Wave Generator."

(a) Square waves, variable in frequency from 3 to 60 cycles in six or more steps; 0 to 20 volts from peak to peak. The highest frequency wave should have wide symmetry adjustment.

(b) 60 to 17,000 cycle square waves; probably generated from an external sine-wave source, with one internal source near high end of audio band. Should give 0 to 20 volts and have wide symmetry adjustment.

(c) 100 kc square wave, 100 kc sine wave, and 10 megacycle sine wave—all locked together in frequency; the square wave variable from 0 to 3 volts, others variable from 0 to 50 volts with phase adjustment on both sine waves.

(2) "Universal Sweep Oscillator"

(a) Nominal frequency variable over i-f range, 8 to 13 Mc; with sweep range up to at least 5 Mc, at rate of about 30 complete sweep cycles per second, a marker oscillator, with good calibration, covering entire range.

(b) Requirements as in (a) with nominal frequency variable over r-f range—approximately 40 to 100 Mc.

(3) Cathode-Ray Oscillograph

A standard, high-quality, 3-inch oscillograph, having a good frequency characteristic over the approximate range of 15 to 100,000 cycles, will probably be useable for many of the common tests. The actual wave-forms and impulses in the various television receiver circuits may be slightly distorted on the screen of this common instrument, but, familiarity with the proper wave-forms will usually serve to allow detection and analysis of improper operation.

A fourth instrument which will be required, though not previously mentioned, is a d-c voltmeter having voltage ranges up to 10,000 volts along with adequate insulation and preferably having at least 10,000 ohms per volt.

In order to completely analyze receiver operation, and to be able to check any element for proper design or functioning, several other units of test equipment will be required. For instance, much more accurate analysis of the entire picture channel can be made by supplying the r-f input from a signal generator which is capable of modulation over the whole video band. A wide range oscillograph, capable of reproducing **square waves** with negligible distortion over the approximate frequency range of 20 cycles to 100 kc, is connected to the Kinescope grid. If now the "Square Wave Generator" is used to modulate the r-f signal generator, properly tuned with respect to the receiver, with square waves of a certain frequency, these square waves should then be observable on the oscillograph. The fidelity with which high and low frequency square waves are thus reproduced is an excellent criterion of proper operation of the picture channel. Trouble can be localized more easily, and the cause more accurately analyzed by using a wide range oscillograph, in this way, at various points in the receiving system. Synchronizing and deflecting circuits may similarly be more completely analyzed with the wide-range oscillograph.

In investigating cases of improper performance, or analyzing faculty design, it may be necessary to investigate the phase and frequency characteristics of the receiving system, or its several parts. In addition to the wide range oscillograph, this requires a beat oscillator or other suitable means of generating sine waves at all frequencies in the video band. Phase characteristics may be obtained by connecting the input and the output of the circuit under test to the two deflecting circuits of the wide range oscillograph, and observing the pattern while the beat oscillator explores the video band.

The above-mentioned r-f Signal Generator, Oscillograph, and Beat Oscillator, together with the four instruments previously described along with commonly available laboratory equipment should be adequate for almost any analyses or tests which might be necessary in the development of television receivers.

It is felt that any discussion of television test equipment as is here given would be inadequate without a special word of caution as to the need for extreme care in work with television equipment in the interest of personal safety. Although the "home tinkerer" will be protected, in so far as that is possible, from high Kinescope voltages in receivers by means of heavy insulation and interlock devices, it is vital that the development engineer and service man constantly keep in mind the fact that potentially fatal voltages may be expected to exist in a television receiver. Large filter capacitors, charged to 5000 volts, store quite sufficient energy to end human life. Thus, where it is necessary to make tests with the Kinescope circuit "hot," a careful procedure should be worked out and adequate precautions taken at all times. Care should be exercised in handling Kinescope tubes when not protected by their cartons or by the safety shield in the receiver. If subjected to impact, bumped sufficiently to crack the envelope, they may explode or implode and hurl glass fragments with tremendous force. With careful handling, however, they are quite safe.

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RMA ENGINEERING DIVISION

INSTITUTE OF RADIO ENGINEERS

ROCHESTER

FALL MEETING

The Annual Convention For Receiver and Tube Design Engineers

Technical Sessions - With up-to-the-minute papers on television, cathode ray tubes, new circuit developments, and other subjects of importance to the radio engineer.

Technical Exhibits - Displaying the latest in component parts and testing equipment for your examination at the opportune time of the year.

Committee Meetings - To save your travel time.

IMPROVED HOTEL FACILITIES THIS YEAR

November 14, 15, 16, 1938

SAGAMORE HOTEL, ROCHESTER, NEW YORK

A. S. T. M. Specifications for Phenolic Laminated Sheet for Radio Use

By R. W. Orr, R.C.A. Manufacturing Co., Inc.

As a result of the lack of any well standardized specifications for phenolic laminated sheet, the radio manufacturer has been able to specify the quality desired only with difficulty and has usually had to rely upon trade names to identify the desired quality. This has limited the flexibility of his purchases and that of his parts suppliers. Now, however, that A. S. T. M., with the cooperation of RMA, has developed specifications for phenolic laminated sheets for radio use, there is basis for definite agreement between the producer and consumer as to the quality of material to be furnished. A means of reference to specific grades of material is provided without the confusion of trade names or other producers' designations. A set manufacturer may specify the quality of material desired in component parts and may be assured of obtaining the grade he wants regardless of the ultimate source of the material.

The **Specifications for Phenolic Laminated Sheet for Radio Applications** (A. S. T. M. Designations: D467-37T) have recently been published by the American Society for Testing Materials. These were prepared by A. S. T. M. Committee D-9 at the request of the RMA Engineering Division.

Six different grades of sheets are covered by the specifications. These are:

Grade No. 1—A paper base punching stock of the type used for sockets, terminal boards, and miscellaneous parts where insulating properties and moisture resistance are of less importance than good punching and assembling characteristics.

Grade No. 2—A paper base punching stock with medium dielectric loss for general use in radio frequency circuits where punching and assembling operations are not particularly severe.

Grade No. 3—A paper base punching stock for simple punched parts where very low losses are essential.

Grade No. 4—A hard paper base material with low dielectric losses for general use in instruments and other applications where parts are produced by machining and where reasonably good appearance and good electrical properties are desired.

Grade No. 5—A fabric base material with medium dielectric losses for applications similar to Grade No. 2 except for more severe punching and assembling operations.

Grade No. 6—A combination paper and fabric base material with medium dielectric losses for tube sockets and similar applications where good punching and toughness is desirable and a tendency to warp is not objectionable.

The specifications cover the punching characteristics, flexural strength and tolerances for the material. The electrical characteristics are specified in limits at a frequency of 1000 kc for the power factor, dielectric constant, loss factor and effect of 24 hours immersion in water on the power factor.

The standard finishes and colors are also defined.

These requirements establish the quality of the material reasonably well for radio applications without having a multiplicity of tests that would cause undue complications.

Additional work is being done by Committee D-9, however, which should permit improving the specifications in the future. Several methods have been developed and others are being investigated for the measurement of the power factor under conditions of dielectric stress parallel to the laminations. This will permit the measurement of losses in the direction in which stresses actually occur in practical use of the material and may also offer a more convenient method of determining the effects of high humidity since the specimens used are smaller and can therefore, be conditioned more readily.

Work is also being done on more convenient and definite methods of testing punching quality. One method that offers considerable promise is the measurement of the Rockwell hardness of the heated material. Several plants are cooperating in correlating "hot" Rockwell hardness and punching quality.

These specifications appear in the A. S. T. M. **Proceedings** for 1938 and also in the **Book of Tentative Standards.** Separately printed copies of the **Specifications for Phenolic Laminated Sheet for Radio Applications** may be obtained for twenty-five cents from the American Society for Testing Materials at 260 South Broad Street, Philadelphia, Pa. An index of all A.S.T.M. specifications and test methods may be obtained without charge from the same address.

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ENGINEERING DEPARTMENT
OF THE
Radio Manufacturers Association

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ORGANIZATION OF THE RMA ENGINEERING DEPARTMENT

With the approval of the Board of Directors of RMA there is now in effect a reorganization of the RMA engineering activities, the desirability of which has long been evident from the experience of the engineering group in the fields of industry standardization and other cooperative Association work. While the new plan of organization does not change the actual functioning of the engineering group, the action of the Board of Directors establishes this group as the ENGINEERING DEPARTMENT OF R.M.A. As against the previous organization arrangements in which the engineering group was subdivided into three sections, the section chairman reporting to the Chairman of the Engineering Committee, the new organization coordinates all engineering activities under the Director of Engineering who, in addition to directing the work of the Engineering Department, is a member of the Board of Directors of RMA and thus supplies the needed contact between the Board and the Engineering Department.

The detailed executive and routine work of the engineering group previously carried on by the chairman of the Standards Section of the Engineering Committee is now the responsibility of the Assistant Director of Engineering, reporting, of course, to the Director of Engineering.

The technical work of the Engineering Department continues to be the responsibility of the many engineering committees which are identical with those under the old organization arrangement but to which have been added a Service Committee and a Safety Committee, the responsibilities of which were previously those of the corresponding "Sections". The RMA Data Bureau continues its work in the collection of broadcast receiver data and vacuum tube type designation assignment and registration.

The procedure to be followed in the development of industry standardization remains unchanged and is more specifically described below in the quotation from the "Organization and Working Rules of the Engineering Department."

Standardization Procedure

"Material for standardization may be proposed by any of the Committees in meeting or through the Chairman of the Committees. Such standardization proposals shall be presented to the Assistant Director. He will then submit such proposals by letter to the members of the Committees concerned and to the RMA membership to obtain written comments or criticism. If in his opinion a meeting of any Committee or Committees is necessary to discuss these proposals, he shall instruct the Chairman of such Committees to call a meeting. After collecting all necessary data, comment, and criticism from all interested groups, the Assistant Director will submit the proposals to a meeting of the Standards Committee for action. When the Standards Committee approves by a vote of three quarters of those present, the proposal shall become, according to the judgment of the Committee, either an:

(A) RMA Standard

Definite Standards may include Definitions, Nomenclature, Symbols; Testing Methods and Apparatus; Performance Ratings, Capacities and Limits; Manufacturing Dimensions and Tolerances; Safety Provision.

(B) RMA Recommended Practice

Any suggestion or practice which, at the time of consideration, may be thought unsuitable for adoption as an RMA Standard, but which is desirable to recommend as uniform practice, may be approved as an RMA Recommended Practice.

Standards and Recommended Practices may be revised, amended, or rescinded by the same procedure."

During the several years that this standardization procedure has been in effect, it was felt that it was very successful, and when standards are finally adopted, they accurately represent the will of the Association.

The present organization personnel of the RMA Engineering Department is as follows:

Director of Engineering	W. R. G. Baker
Assistant Director	VIRGIL M. Graham

Committee on Broadcast Receivers, E. T. Dickey, Chairman
Committee on Vacuum Tubes, R. M. Wise, Chairman
Committee on Component Parts, L. C. F. Horle, Chairman
Committee on Sound Equipment, H. S. Knowles, Chairman
Committee on Television, A. F. Murray, Chairman
Committee on Facsimile, E. W. Engstrom, Chairman
Committee on Automotive Radio, J. H. Pressley, Chairman
FCC-RMA Conference Committee, G. E. Gustafson, Chairman
Safety Committee, H. C. Sheve, Chairman
Service Committee, H. A. Crossland, Chairman.

In addition to the above there are a number of subcommittees which handle special details of the work of several of the committees.

THE RMA STANDARD INTERMEDIATE FREQUENCY

By G. E. Gustafson, Zenith Radio Corporation

For several years the standardization of the frequency of operation of the I.F. amplifier in superhetrodyne receivers was discussed in the industry resulting finally, in September of 1936, in the organization of a special committee on this subject. The work of this Committee resulted in the choice of 455 K.C., for this Standard, and assurance as to its protection obtained in September of 1937 from the Federal Communications Commission as follows:

"This is with reference to our letter of January 25, 1937 and in further reply to your letter of January 21, 1937 enclosing recommendations for allocation by the Federal Communications Commission of the frequency 455 kc as a protected intermediate frequency for the radio manufacturing set industry.

"In addition to the study of this problem by the Federal Communications Commission, the Interdepartment Radio Advisory Committee was requested to cooperate with the Commission to the end that all services, including those operated by the various Federal Government departments might afford the desired protection on 455 kc.

"At a meeting of the Interdepartment Radio Advisory Committee on April 26, 1937, the following resolution was unanimously approved.

> "The Committee recognizes that unification on the use of the frequency 455 kc as an intermediate frequency for superhetrodyne receivers is desirable for design purposes; that it may cause some trouble from an interference standpoint in Alaska; that it is desirable to limit further expansion of transmission in the band, 450-460 kc within the continental limits of the United States."

"The Federal Communications Commission will endeavor to protect this frequency by not authorizing any new frequency assignments in the band, 450 to 460 kc. In this connection we wish to emphasize that wherever frequencies within this band are now licensed, their use will continue in the future. In addition it is to be understood that the future requirements of individual services may necessitate a change in this policy, in which event the Commission will inform your Association of any contemplated action which might give rise to the possibility of interference resulting to broadcast reception on receivers using the intermediate frequency of 455 kc."

In choosing 455 K.C., as a Standard, this Committee had the following facts in mind:

1. This frequency offered less danger of interference from stations operating on or near the I.F. than other frequencies in the range 440 to 480 K.C.
2. The second harmonic fell on 910 K.C., a channel not used by United States Stations. Since no practicable method has been found for the elimination the "tweets" produced at the second harmonic of the I.F., the Committee felt that this choice would be very helpful in relieving this difficulty.
3. Since all frequency assignments made to broadcasting stations differ by multiples of 10 kilocycles the "tweets" produced by local stations operating at frequencies differing by an amount approximating the I.F. are reduced since the "tweet" produced is 5 kilocycles, instead of zero frequency.

Thirteen of the 17 major Companies in the industry are using this new I.F. this year.

Unfortunately, at the Havana Conference the Federal Communications Commission made plans for the change of frequency assignments to many assignment stations in the broadcast band. Among the changes that are planned is the assignment of stations to 910 K.C., which would nullify the benefits listed under number two above. This plan incidentally does not call for any United States station assignments on 900 kilocycles.

The attention of the FCC has been called to the seriousness of this situation by the RMA and strong representation have been made against the assignment of stations to 910 kilocycles. The RMA has recommended that if interchanging of assignments to 900 and 910 kilocycles cannot be made, the FCC refrain from assigning stations to the latter frequency.

There were some indications that had the RMA been represented at the Havana Conference and had there been heard regarding the importance of maintaining the 910 kilocycle channel clear of the United States assignment, this may have been accomplished. At least a closer contact with the FCC was indicated and for that purpose Dr. W. R. G. Baker has appointed a committee known as the FCC-RMA Conference Committee.

This Committee has been functioning since April 1938 and has already met with the FCC Engineers on several occasions. On April 29th, 1938 it presented a Resolution to the FCC recommending no station assignments to 910 kilocycles. At this same meeting it discussed a survey conducted by the RMA on cross-talk conditions at Seattle, Washington. The Commission in turn requested information on AVC., characteristics of broadcast receivers and for recommendations on standards for radio noise measurements. A portion of this data has been forwarded to them and the remainder will be forwarded as soon as the RMA Data Bureau has secured representative data on radio receivers manufactured during the current season.

The F.C.C.-R.M.A. Conference Committee appeared for RMA at an informal conference on September 19, 1938 which the engineers of the F.C.C. had called for discussion of proposed rules and regulations governing the operation of low power radio frequency devices. A notice of this conference had been previously forwarded to all R.M.A. Members by Mr. Bond Geddes.

At this conference the concurrence of the R.M.A. with the F.C.C. engineers on these proposed rules and regulations was expressed.

TELEVISION R-F INPUT CIRCUITS

By H. T. Lyman, General Electric Co.

Introduction

It is easily understood how, as the result of the multitude of synchronizing, sweep, and video problems which beset him, the television receiver designer should consider the RF input circuits as warranting little immediate attention. In view, however, of the fact that in television the limit of the service area is reached so rapidly and consequently performance at marginal field strengths must be contemplated it follows that RF input circuits must be carefully considered. With this in mind, calculated performance curves for several television input circuits are here shown and the performance of a typical RF unit is described.

As in the case of sound broadcast receivers, the gain and selectivity of the input and of the converter stages are the items of primary importance. Many other items are common to both types of receivers, but those that are strikingly different are:

First: The restriction in number and spectral location of the television channel assignments. This favors station preselection.

Second: The broad RF band-width required in each television receiver channel in order to pass both video and audio carriers.

Third: The low impedance of circuit elements at television RF frequencies and the cosequent low gain for a given band-width.

Fourth: The interference that may be inaudible in the audio channel but which may seriously impair the video signal. This is particularly true of direct intermediate frequency pickup or of cross-modulation IF interference products in the converter.

Each circuit ahead of the converter or first detector is important in affecting the signal-to-noise ratio since after initial detection, practically nothing can be done to improve this ratio that will not of itself cause loss of picture detail. That is, experience has shown that a picture detail control analogous to the sound broadcast tone control is of very little practical value, since the average eye is so much more rigorous than the average ear in demanding faithfulness of reproduction.

In discussing these peculiarities of television RF input circuits, the start will be made with the antenna, input line, and input transformer as a unit. Then the RF amplifier, the converter and finally the local oscillator will be discussed.

Antenna Circuit

Although many types of doublet and multi-wire antennas have been proposed for television reception, a doublet antenna and balanced transmission line will be taken as representing the average television antenna and input circuit.

It is necessary that the primary of the antenna transformer which terminates the line present a fairly uniform impedance to the line in order that line reflections be kept at a minimum. This immediately suggests the advisability of tuning this primary for each station channel. Since tuning or switching is considerably simplified if an untuned fixed primary is used it may be interesting to examine a typical example of such a circuit, and to compare it to the case of a double-tuned antenna transformer.

Figure 1 shows the design constants and performance characteristics at three points in the television band of an untuned primary transformer working into a typical tube grid load. The primary inductance is taken equal to the line surge impedance at the lowest frequency, and the coupling and the Q of the secondary are adjusted for maximum gain at the band-width of 5.6 MC for an attenuation of $\sqrt{2}$.

Inspection of the curves and of the gain formula shows that if the secondary capacity is kept constant, which results in a circuit Q which is proportional to frequency, the gain and band-width are maintained nearly constant by varying the transformer coupling inversely as the square root of the frequency.

If a shunt load is applied to the primary to make the line termination more nearly perfect, the gain will be decreased slightly, but the general shape of the selectivity curves will not be altered greatly.

The broad-nosed curve is the approximate frequency characteristic of the combination of a doublet with a balanced and properly terminated transmission line.

The approximate overall selectivity curves from antenna to RF amplifier grid resulting from the assumption that one doublet is used for the entire television band are shown as dash-line curves.

In a practical RF input unit design it has been found that the extraneous losses at the high end of the band

UNTUNED PRIMARY ANTENNA TRANSFORMER
GAIN CHARACTERISTIC

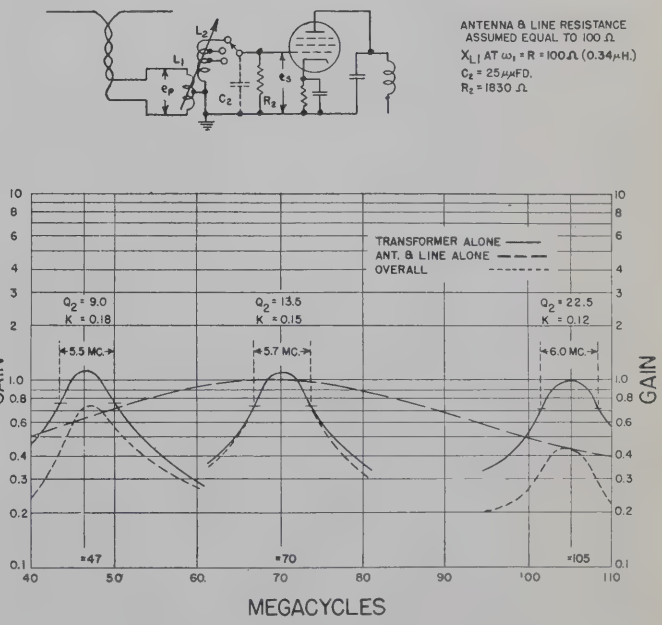


FIG. 1

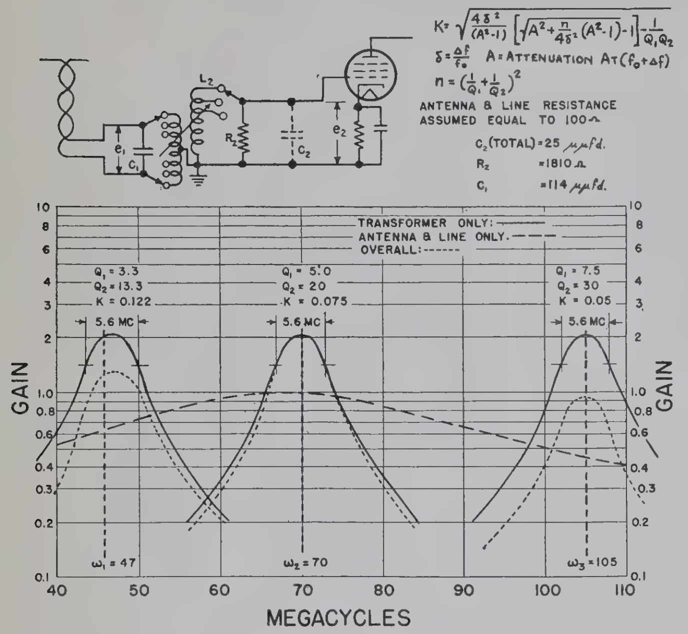

TUNED PRIMARY ANTENNA TRANSFORMER RESPONSE CHARACTERISTIC

FIG. 2

are so severe that it is better to compromise on increased coupling and increased band-width in order to keep the gain more nearly uniform.

Figure 2 gives similar design constants and performance curves for the case in which the antenna transformer is double-tuned.

The signal gain under the conditions shown is approximately double that of the untuned primary case. A solution has been obtained for the coupling coefficient to be used for a given band-width. The equation is:

$$K=\sqrt{\frac{4\partial^2}{(A^2-1)}\left[\sqrt{A^2+\frac{n}{4\partial^2}(A_2-1)}-1\right]-\frac{1}{Q_1\,Q_2}}$$

Where $\partial=\pm\frac{\triangle f}{f_o}$

$A=$attenuation at $(f_o\pm\triangle_f)$

$$n=\left(\frac{1\ +\ 1}{Q_1\ +\ Q_2}\right)^2$$

$$Q_1=\frac{R_1}{WL_1}=\text{primary performance factor}$$

$$Q_2=\frac{R_2}{WL_2}=\text{secondary performance factor}$$

The gain equation is

$$G=\frac{WK\sqrt{L_1\,L_2}}{\left(\frac{1}{Q_1\,Q_2}+K^2\right)}$$

Inspection of these formulas shows that if inductance tuning is used, namely, if all circuit constants are fixed except the transformer windings, constant gain and constant band-width—expressed in frequency and not in a percentage of resonant frequency—are maintained by varying the coupling inversely as the first power of the resonant frequency. This contrasts with the untuned primary case in which the coupling is varied inversely as the square root of the resonant frequency.

The effect of a single doublet on the overall frequency characteristic is shown again by the dash-line curves. Again it must be pointed out that transmission line losses which in the average case increase directly with frequency, as well as extraneous circuit losses which in the average RF unit increase rapidly near 100 MC, make it difficult to hold the gain up and the band-width down. Hence departures from the conditions shown be required at the high end of the band.

The Q of the primary, Q_1, has been chosen as low as 5 in order to keep the line terminating impedance fairly uniform to minimize line reflections, and to make it possible the use of a fixed primary capacitor of ordinary capacitance tolerance. Otherwise the gain can be increased still further.

In cases of severe low frequency interference such as that produced by amateur stations, it has been found very desirable to insert a balanced high-pass filter in the line at the receiver, the cut-off frequency of the filter being 35 MC.

RF Amplifier

In regions of marginal field strength the shot noise of the first tube is often the limiting factor in the picture resolution. It is important then to compare from the standpoint of plate circuit noise otherwise suitable tubes of high mutual conductance low plate current.

In Figure 3 has been tabulated the data essential to such a comparison. This indicates that the 1853 and 1231 are equally desirable and distinctly better than any others there shown.

Using the 1853 tube as an example, because of its extended cut-off characteristic, Figure 3 also gives a calculation of the signal-to-noise ratio in the plate circuit.

The ratio of 57.2 to 1 is not too good for a satisfactory picture, but it has been found that definite entertainment value exists with as low a ratio as 20 to 1. Hence the minimum field strength that can be utilized with the RF input system here described is—

$$\frac{20}{57.2}\times\frac{1000\ \mu v}{\text{meter}}=\frac{350\ \mu v}{\text{meter}}$$

This figure must undoubtedly be raised to the generally accepted figure of 1000 μv/meter in urban districts or where local interference such as of the ignition type may be the limiting factor.

Converter (First Detector)

With the RF amplifier supplying a good signal-to-noise ratio at the grid of the converter, the problem is then to employ the tube with the highest conversion conductance and lowest input and output capacitances. For this the figure of merit is obviously the ratio $\frac{S_c}{C_i+C_o}$.

In figure 4 have been tabulated the characteristics of a number of tubes along with this figure of merit. The superiority of the 1852 is quite marked.

In order to obtain maximum gain in the RF amplifier the output capacity of this tube and the input capacity of the converter can be used as shunt elements of a band-pass filter as shown in Figure 5. By this means the gain can be nearly doubled as compared to that of a single-tuned shunt plate-grid circuit.

Noise Figure of Merit $= \dfrac{0.46\ G_m \sqrt{R_G}}{\sqrt{I_P}}$

Tube Type	G_m	$I_{P(ma)}$	$\frac{G_m}{\sqrt{I_p}}(\times 10^2)$
6D6	1600	8.2	1.77
6K7	1650	10.5	1.61
6L7	1100	5.3	1.51
58	1600	8.2	1.77
78	1650	10.5	1.61
956	1800	5.5	2.42
1853	5000	12.5	4.47
1231	5000	12.5	4.47

Calculation of Signal-to-Noise Ratio

Grid Thermal Noise $= E_{TG} = 1.28\sqrt{R_G\ F}\ \ (10)^{-10}$ Volts RMS.

Where: R_G = Grid Load Resistance = 1800 ohms
F = Receiver Video Bandwidth = 4 MC
Solution: $E_{TG} = 11$ Microvolts.

Grid Signal: $\equiv E_{SG} = \dfrac{\text{EAntenna} \times \text{Attenuation of line}}{\sqrt{2}} \times \text{Transformer Gain}$

EAntenna = Eh = Field Strength × Effective Height

$h = \dfrac{\lambda}{\pi}$ For Doublet at Resonance

In present case, assuming $E = 1000\ \mu v$/Meter
$f = 70$ MC, $\lambda = 4.28$ Line Attenuation = 2.0
$E_{SG} = 960\ \mu$-volts RMS

Plate Shot Noise $\equiv E_{SP} = 2.82\ Z_P \sqrt{I_P}\ F\ (10)^{-10}$ Volts RMS

Using 1853 because of its extended cut-off and
$Z_P = 1000$ ohms, Gain $= G_m\ Z_P = 5$
$E_{SP} = 63$ Microvolts

$$\frac{\text{Signal-to-noise Ratio}}{\text{(In Plate of 1853)}} = \frac{E_{SG} \times \text{Gain}}{\sqrt{(E_{TG} \times \text{Gain})^2 + (E_{SP})^2}} = 57.3$$

FIG. 3

Comparison of Converter Tubes

Tube Type	S_c	Capacities		$\frac{S_c}{\Sigma C}$
		Input C_i	Output C_o	
6A8	500	12.5	12.5	20
6L7	350	8.5	12.5	16.7
ACTH1	870	8.8	11.5	42.7
6K7	676	7	12	35.6
956	738	2.7	3.5	119
1852	3300	11	5	206
1231	1830	8.5	6.5	122
6K8	350	6.6	3.5	34.6

FIG. 4

The shape of the frequency characteristic and the design formulas are also given in this figure.

As for methods of coupling to the oscillator, the only satisfactory method so far has been found to be a combination of inductive and capacitive coupling of the converter grid to the oscillator tank as shown in Figure 5. A single turn in the grid lead coupled tightly to the oscillator coil is satisfactory and will not upset the band-pass filter termination or load the oscillator too seriously even at 100 MC.

TELEVISION RECEIVER R.F. UNIT
CONVERTER COUPLING CIRCUIT

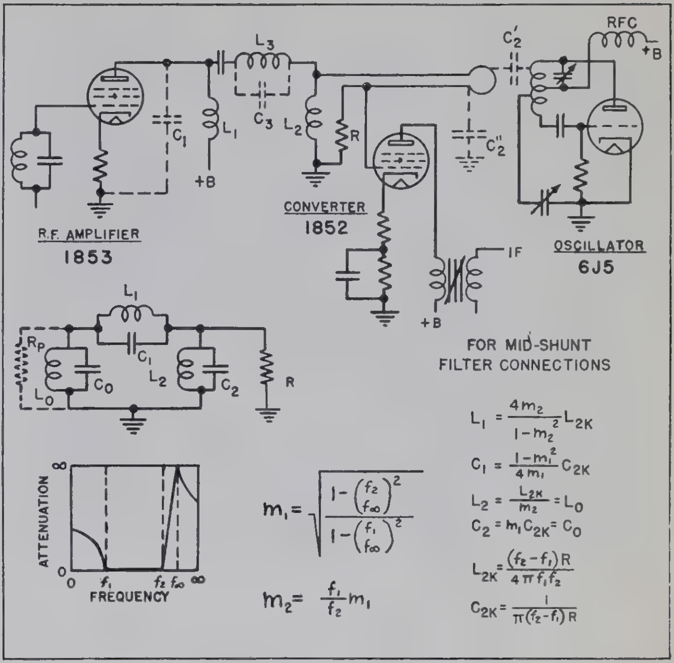

RFC
+B
C_2'
L_3
C_1
L_1
C_3
L_2
R
C_2''
+B
CONVERTER
1852
R.F. AMPLIFIER
1853
OSCILLATOR
6J5
IF
+B
L_1
R_P
C_1
C_0
L_0
L_2
C_2
R
FOR MID-SHUNT FILTER CONNECTIONS
ATTENUATION
∞
0
0
f_1
f_2 f_∞ ∞
FREQUENCY
$m_1 = \sqrt{\dfrac{1-\left(\frac{f_2}{f_\infty}\right)^2}{1-\left(\frac{f_1}{f_\infty}\right)^2}}$
$m_2 = \dfrac{f_1}{f_2} m_1$
$L_1 = \dfrac{4m_2}{1-m_2^2} L_{2K}$
$C_1 = \dfrac{1-m_1^2}{4m_1} C_{2K}$
$L_2 = \dfrac{L_{2K}}{m_2} = L_0$
$C_2 = m_1 C_{2K} = C_0$
$L_{2K} = \dfrac{(f_2-f_1)R}{4\pi f_1 f_2}$
$C_{2K} = \dfrac{1}{\pi(f_2-f_1)R}$

FIG. 5

Local Oscillator

In deciding upon the proper tube and circuit for the local oscillator, the three major factors to be considered are—

First: The value of the ratio $\dfrac{G_m}{C_g + C_p}$ for the oscillator tube and circuit.

Second: Oscillator power output capability at UHF.

Third: Stability of the oscillator circuit and tube with respect to supply fluctuations.

Figure 6 gives a tabulation of the characteristics of a few tubes pertinent to their use as UHF oscillators. The superiority of the 955 is quite apparent, but amongst the standard tube types the 6J5 is outstanding. Since the transit time loading of this tube at 120 MC is not very serious, and since it can excite the 1852 grid with at least three volts up to 120 MC, it is quite satisfactory.

Comparison of UHF Oscillator Tubes

Tube Type	G_m	C_g	C_p	$\frac{G_m}{\Sigma C}$
955	2000	1.0	0.6	1250
6J5	2600	3.4	3.6	372
6C5	2000	4.0	13.0	118
6J8G Osc. Section	1600	11.7	5.5	93
6K8 Osc. Section	2400	6.0	3.2	261

FIG. 6

Since tuned plate oscillator circuits have been shown to give much greater stability against voltage fluctuation than tuned grid circuits, particularly at UHF, the former of these types of oscillator circuits has been incorporated in the television RF input unit shown in the photograph of Figure 7.

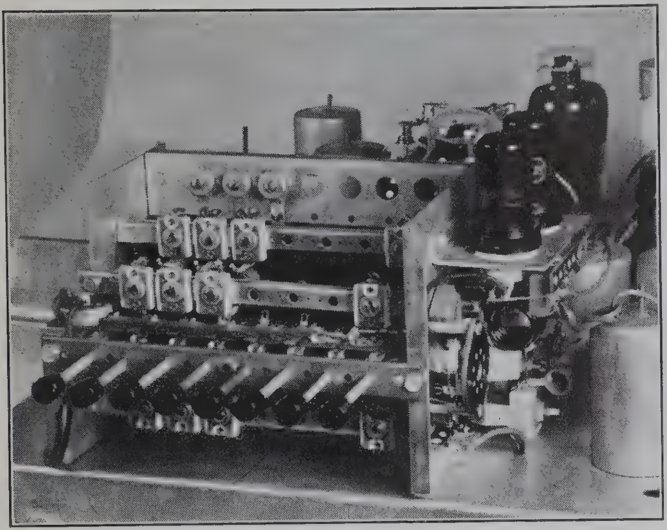
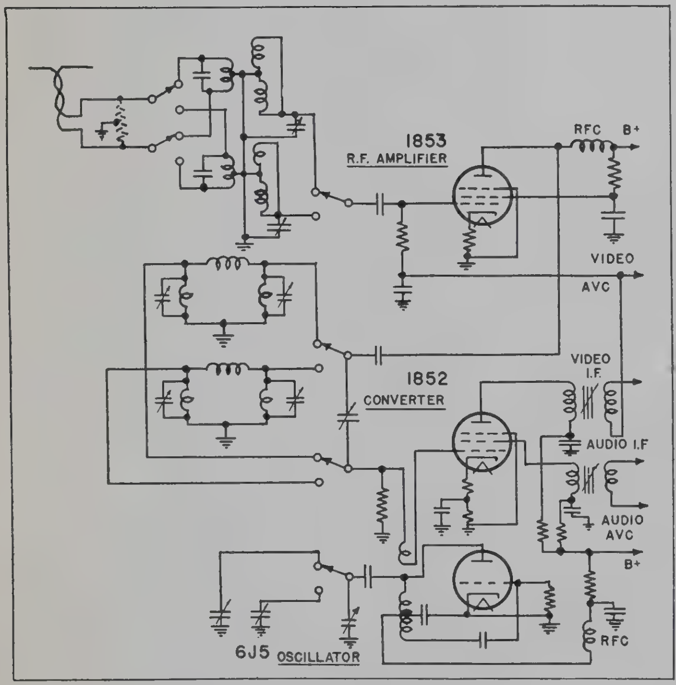


Fig. 7



TELEVISION RECEIVER
R.F. UNIT
SCHEMATIC
SHOWING CONNECTIONS FOR TWO CHANNELS ONLY

FIG. 8

This shows on the left the antenna wave-trap or high pass filter at the transmission line input. Low frequency push-buttons and circuit elements are at the left, with the highest frequency circuit next to the tubes on the right.

The tubes are:

1853—RF amplifier operated with video AVC.
1852—Converter.
6J5—Local oscillator.

The oscillator vernier capacitor to take care of drift not capable of being compensated for in the oscillator trimmers is shown on the right side of the unit.

All trimmers are accessible from the front of the unit.

The antenna buses, coils and trimmers are on the bottom of the switch, with the interstage filter and oscillator buses, coils and trimmers on top. It will be noted that it is necessary to sectionalize switch contacts of the two highest frequency circuits to eliminate shunt loading that would otherwise be as low as several hundred ohms at 100 MC.

The circuit of this RF input unit is shown schematically in Figure 8 and includes the optimum circuit arrangements that have been described.

The performance characteristics of unit shown in Figure 9 show mainly that even with switch sectionalizing that results in practically uniform conversion gain, the circuit loading ahead of the converter grid is so severe at 105 MC that gain and band-width at the high end of the band suffer considerably.

Effort is now being applied to new mechanical layouts particularly to improve this situation.

Conclusion

While it is realized that it is doubtless still too early in the development of commercial television receiver designs to predict what the design trend will be, it is hoped that this discussion of some of the considerations important to the design of RF input circuits will be helpful. Theoretical conditions for uniform gain and band-width have been established, tube comparisons have been given, and an RF unit reduced to the point of commercial design has been described.

PUSH BUTTON R.F. UNIT
GAIN CHARACTERISTIC

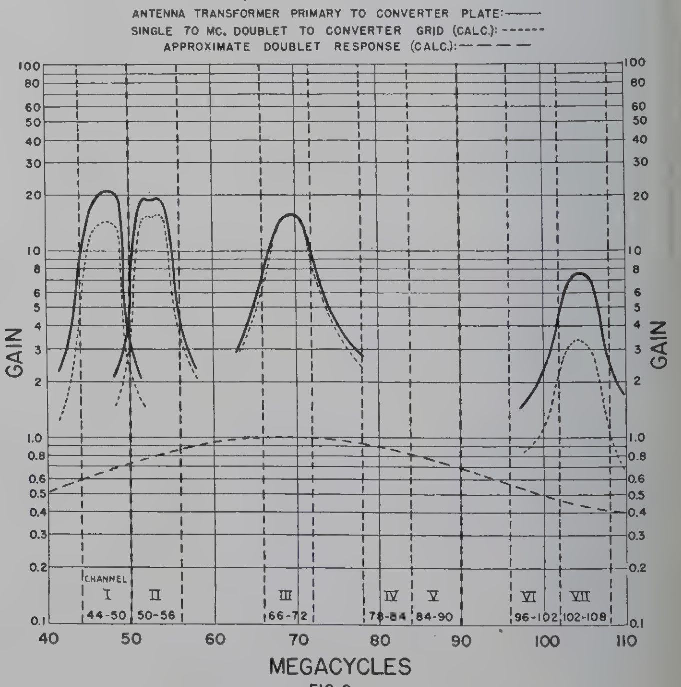


FIG. 9

THE MEASUREMENT OF RADIO NOISE INTERFERENCE

By C. J. Franks, Ferris Instrument Corporation

From both the technical and the legislative viewpoints, interest in the problem of the reduction of radio frequency noise interference continues to increase. The success of any attack upon such a problem depends primarily upon an ability to measure the magnitudes of the quantities involved; it is impossible to compare noises, to state limits of acceptability, or to evaluate remedial measures without the ability to state results in terms of commonly known and accepted units.

The measuring equipment available for determining the magnitude of radio noise interference in the past has generally been considered unsatisfactory, but it was useful largely, perhaps because nothing better was at hand. No sound criticism can, however, be made of the designers of the early instruments either on the grounds of lack of diligence or of failure to take into account all of the factors involved in the measurement of noise; the knowledge of how to do the job properly was not then available to anyone.

It would be highly gratifying to be able to announce that this knowledge is now at hand and that all of the problems of radio noise interference have been solved. Unhappily however, this is not the case. Today we know a little more about noise measurement than was known five years ago and new noise meters which indicate more nearly correctly the effect of all types of noise can now be built. But the fact is that they are still a long way from the ideal which is, in fact, the subject of this paper.

This paper is therefore offered with the hope that by clarifying the situation, in placing a statement of our present position upon the record others will be encouraged to continue the work leading toward a more complete solution of the problem of designing a noise meter which will at the same time be commercially acceptable and will also give the correct answers.

It is necessary to begin with an apology for the introduction of another new term, namely, the Interference Effectiveness Factor, abbreviated IEF. Its usefulness lies in the simplification it accomplishes; we define it as a number which accurately represents the actual ability of any radio frequency disturbance to cause interference with radio reception. At present it can be only a concept, for the various factors which influence it cannot be stated in terms of known quantities; even its dimensions are unknown. This however need not reduce its usefulness to the present discussion.

The radio frequency wave forms which are called noise interference have characteristics of amplitude vs. time which cover a wide range of values. On the one hand are waves of almost uniform amplitude, closely spaced in time, with high energy content, but often having a low interfering capability compared to their energy. At the other extreme are the widely spaced, highly peaked pulses of very low energy content such as those associated with ignition systems. The design of an instrument which will accurately measure the IEF of these extreme and of all intermediate wave forms is the concrete problem which faces the instrument designer. Additionally, practical considerations require that a suitable instrument have light weight, compactness, ease and rapidity of operation, a scale direct-reading in IEF units, a self-contained design, together with moderate cost, if the finished instrument is to be commercially acceptable as well as electrically correct. As is usually the case, the complete attainment of all these desiderata is impossible and many compromises must be made.

The actual wave forms of the various types of noise voltage might at first thought seem important, but any interest which they may have in the general problem is purely theoretical. This is partly due to the fact that it is impossible to determine these wave forms. But even if they could be determined the information would be of little practical use except to the research worker. The point here being that it is not the original wave form of the disturbance that causes interference with program material, but rather it is an audio wave form, differing greatly from the original wave form which caused it, which issues from the loudspeaker and causes the interference. The user of the radio receiver obviously cares nothing about the wave form of whatever is entering the antenna circuit of the receiver, but he is very much concerned about the noise in his loudspeaker. Our line of attack must adopt the same attitude; our statements of the problem have recognized this fact, and in our definitions and terms we admit it. We see that it will be necessary to start at the beginning, placing ourselves beside the average listener, before the average loudspeaker of his average radio receiver, and listen with him to the noise while a program is being received, rating the noise in terms of its ability to interfere with the enjoyment of the program. Only when all of the steps of this procedure are properly carried out will the true IEF of the noise be determined. The equipment which will have been used in making the measurements will then constitute the pattern for an ideal IEF meter.

Figure 1 shows the elements of this ideal IEF meter in functional form. Unfortunately it also shows how impossible of attainment is the actual design of a practical equipment for field use. Some of the elements of the system are familiar and easy to make, but some of them are rich in uncertainty, while others are hardly the sort of thing that could be included in equipment for use in the field.

In this hypothetical measuring system the radio impulses whose IEF is to be determined are picked up from a radiation field by means of an exploring antenna, or optionally by a direct coupling connection from any lines or conductors on which they may appear. They are then amplified to a measurable magnitude by a radio receiver. In passing through the receiver their form and energy content are greatly modified by the selective and energy storage properties of the tuned circuits, by overloading and non-linearities in the tubes, and by resonances in the electro-acoustic system. No matter what the form of the original exciting pulses, after passage through the receiver they all have the form of damped wave trains. Only the spacing of the trains in point of time, and to some extent the amplitude, depend upon the original wave. The damping, which

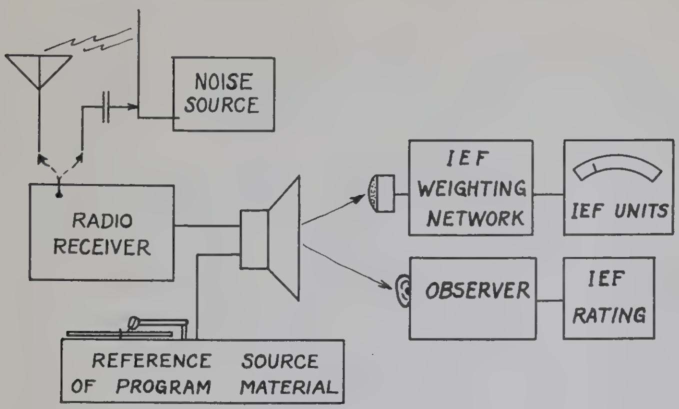


Fig. 1

largely controls the energy content of the individual train, depends almost entirely upon the receiver. The total noise energy output therefore is determined not only by the fundamental frequency of the noise, or pulse repetition rate, but also by the receiver characteristics. From this can be drawn two important conclusions. The first is that the energy output of a receiver is related to the IEF in no simple manner, and any indicating device whose indications are proportional to the noise energy output will not give true readings of IEF on all types of noise. In view of the fact that all practical indicating devices are energy-operated, this carries considerable potential embarrassment for the instrument designer, and is indeed the first important obstacle in the way of building a satisfactory IEF meter.

The second conclusion is that the characteristics of the radio receiver to be used in this work must be carefully standardized and maintained in order that consistent and correct results may be obtained by different observers under a variety of different measuring conditions. In proof of this it is only necessary to refer to an experience which most radio engineers have had, that of listening to a comparative test between a low-fidelity and a high-fidelity receiver under conditions where some noise is present. The IEF of the noise in the high-fidelity receiver is always the higher.

Thus far we have walked the safe, familiar ground of experience, but the remaining elements of the IEF measuring system lead into unknown and difficult territory. These elements include a standardized loudspeaker into which the noise output of the receiver is fed, a source of program material for comparison, and an IEF weighting and indicating system, consisting either of a human observer or an equivalent electrical network. The indicating system picks up the combined program and noise and weighs the interfering capabilities of the noise, giving the answer directly in IEF units. The possession of one of these ideal IEF meters would permit anyone to rate directly, any type of noise voltage produced by any type of electrical equipment or appliance in terms of the actual interference it produces. Also, the true effectiveness of any noise-reduction measures applied to the equipment could be determined directly, by a before-and-after test, and the correct answer obtained regardless of whether the noise reduction was accomplished by a change of wave form of the noise or by a mere attenuation of amplitude of the voltage.

The instrument designer's job is to take the elements, properties, and performance of this ideal IEF meter and from them work out his practical design. In the process of achieving commercial acceptability some theoretical correctness inevitably is lost. It will be entertaining, although perhaps, not highly constructive, to follow through the process in detail and consider each system element in turn.

First of all, we can certainly say that the human observer with his prejudices, personal equations, and dependence upon external influences is definitely out of the question. Experience teaches that as long as human judgment is required in a measurement, the accuracy and reliability of the measurement are questionable. It will therefore be necessary to design and provide an electrical network to perform the function of weighting the noise against the program and thus replace the human observer. This assumes that it is possible to determine his equivalent circuit.

The loudspeaker and microphone shown as a link in the measuring system must be the next to go. Although the frequency characteristic and resonant properties of the loudspeaker undoubtedly affect the results obtained in a measurement, electro-acoustic elements are too uncertain as to stability of calibration and too bulky and heavy for inclusion in a portable equipment. There is no alternative but to eliminate them, replacing them by a direct electrical connection between radio receiver and weighting network. A system so simplified will probably be incapable of giving a precisely correct result, but this source of incorrectness seems insignificant when certain additional simplifications soon to be mentioned are considered. Next in line for the designer's axe is the reference source of program material. This is an important factor in the IEF measurement, but it is also very difficult to utilize in a practical measuring system, for the amount of noise interference which can be tolerated depends so largely upon the type of program material. Thus, only an otherwise negligible amount of noise may completely ruin the enjoyment of a pianissimo passage of a symphony while as an accompaniment to some of the wilder varieties of swing a tremendous noise addition may not only be indistinguishable but even be contributory to the effectiveness. The only possible conclusion is that this source of complication, together with its contribution to the weight and bulk of the equipment, must be eliminated entirely. The IEF weighting function will then be performed on a basis of the properties of the noise only, with no program comparison, and this is an additional assurance that the practical measuring system will **not** rate the noise IEF in accordance with the theoretically correct method.

Figure 2 shows the elements that remain after the above eliminations. All we have left is a radio receiver, weighting network, and indicating instrument, which would seem to be the ultimate in simplicity, but the fact is that this requires still further compromise before the practical measuring instrument can be built.

The difficulty here involved lies in the IEF weighting network, which is, indeed, the heart of the measuring system. This network should be the equivalent circuit of a human being, so that its action in rating the IEF of all types of noise will be exactly the same as the action of the average human listener. The difficulty arises from the fact that we do not yet know the equivalent circuit of a human being; we do not know upon what

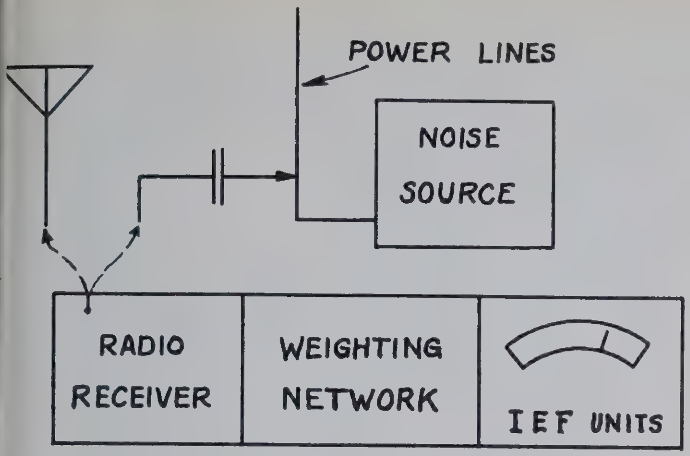


Fig. 2

factors his IEF rating of a noise depends, or to what extent each of these factors enters into the result. It is reasonably certain that the interfering effectiveness of a noise depends to some extent upon the loudness of the program, the ratio between noise and program, the predominant frequencies in each, possibly upon some additional minor factors, and finally, in major degree upon the amplitude vs. time characteristics of the noise. The amount by which each of these factors enters into the result, and the proportionality law of its effectiveness, are unfortunately not known with any certainty. Until they are known, the perfect noise meter cannot be built, but the magnitude of the task of determining such complex relationships indicates that a long time will probably elapse before they can be completely investigated.

Any person inclined to minimize the difficulty of obtaining the necessary data by a subjective study of the effect of noise upon the enjoyment of program material is referred to the published work of the Bell Telephone Laboratories with reference to similar studies of the effect of acoustic noise upon hearing acuity, a distinctly simpler problem than is here discussed. These studies have involved tens of engineers, hundreds of subjects, and thousands of tests, yet it is probable that those who have carried on this work would be the first to deny that they had exhausted the possibilities of the investigation and arrived at a complete and satisfactory answer to the problems involved. Assuming the extremely remote possibility that similar studies could be made of the radio noise problem by interested, competent, and solvent parties, there would then remain only the designer's problem of setting up a network which would take into account all of the factors in proper proportion and with the proper law of variation so that this net work would correctly rate any type of noise in IEF units.

The logician will by this time have concluded that the building of an IEF meter is an impossibility and indeed, he will probably decide that it should not even be attempted for some ten or twenty years or until human knowledge has had opportunity to overtake desire. We, however, shall abandon the logician to genteel and uninteresting starvation while we proceed to design a noise meter—any noise meter—for those who have less sympathy for logic than they have desire to measure noise; not ten years or even one year hence, but right now. They demand noise meters in no uncertain terms and the instrument designer builds noise meters for them and if, necessary, simultaneously quieting the cries of his scientific conscience by writing papers in which he admits that his solution is not the ideally correct one but is the best he can do with the available knowledge.

We have seen that the IEF of a noise depends upon several different characteristics of the noise and of the system; each factor enters into the result in a greater or lesser degree. The degree is usually not known. It would seem that the best method of simplifying the entire problem so as to arrive at a practical answer is to estimate the probable importance of the various factors, eliminating from consideration those which seem unimportant. The network is then set up on the basis of the remaining probably major factors. In the noise-meter problem, the amplitude vs. time characteristics of the noise constitute the most important single factor, and can probably be taken as the sole basis of measurement. What then shall be the relationship, or proportionality law, between these characteristics and the resulting reading of IEF? Here again the available knowledge is pitifully inadequate for purposes of design; such individual facts as are known or are guessed are chiefly of a negative nature, and not much help to the designer.

For example, suppose it is assumed that the peak value of a noise wave is the true measure of its IEF, so that the problem of building the IEF meter could conveniently be solved by merely providing the output of the radio receiver with a peak-reading voltmeter. The fallacy of this assumption is shown by comparing the interfering effectiveness of two waves having equal peak amplitudes, hence equal meter readings, but different repetition rates. A noise pulse occurring once each second will certainly have a different IEF from a disturbance having peaks occurring 1000 times per second! Evidently the peak voltmeter is not the correct answer.

Suppose then that an average-reading type of output meter, whose indications are proportional to the energy content of the wave, is tried. As in the case of the peak meter, it is easy to show by means of readings on waves of the same energy content but different peak factors, that the IEF of a noise wave is definitely not proportional to its energy content. The comparison can be made theoretically, on paper, or subjectively, with actual human subjects and noises of varying character to which they listen, but the answer is the same either way—the average reading meter is wrong, and any instrument using one is wrong, and that includes all of the noise measuring instruments in general use today.

It is probable that the response law required to give IEF readings proportional to the actual interfering effectiveness of a noise wave lies somewhere between the two extremes considered. Unfortunately we do not know just where in this middle region it lies, nor is there any assurance that it will remain constant under the influence of other factors, perhaps some of those already discarded for purposes of simplification. For example, the response law for high noise levels may well be different from that at low levels; there is a rather strong suspicion in some quarters that this is true. It would probably be possible to build an indicating system with a response law which changed with level if only the required change pattern were known. However, until the task of determining all of these factors is performed, by subjective tests upon human beings under all possible conditions and combinations of noise and program, employing an acceptably systematic, scientific procedure, we must be willing to admit that any practical measuring system which we can set up can only be the result of reasonably intelligent guesswork. If it proves to give results which seem significant, reasonable, and in agreement with experience, a large part of the credit must be given to happy accident.

In looking around for some sort of data on which to base a hopefully intelligent guess as to the meter law, we are careful not to overlook any work by other agencies which bears upon the problem. The various European countries have proceeded more rapidly toward regulation and restriction of interference-producing devices, and their measuring art is correspondingly standardized. Their coordinating bodies such as the committee of experts of the C.I.S.P.R. (roughly translated this means Special International Committee on Radio Disturbances) have set up complete specifications for instruments to be used in the measurement of radio noise. These specifications have been adopted by the governing bodies of the various countries, and instruments conforming to them are in use in noise measurement work. The indicating circuits of these instruments are of a quasi-peak reading type, the constants being specified so as to require that peaks must persist for a definite time, that is, have a definite energy content, in order to result in a meter reading. It is probable that this sort of tie-up between the peak value and the energy content of the wave being measured results in a response law which comes fairly close to the proper one, at least as close as a single response law can come in view of some of the considerations previously mentioned. We believe that IEF depends upon the peak of the wave, though it is certainly not proportional only to peak amplitude; we are equally sure that it depends upon energy content, though not in direct proportion. The European compromise between these two extremes looks as though it might hit fairly close to the truth, and in lieu of more exact knowledge we can hardly hope to do better than to adopt their ideas in entirety.

Figure 3 shows a view of a noise meter designed in general conformance with the C.I.S.P.R. specifications. Since the measuring circuits operate on a response law different from the average-reading law now so widely employed in noise meters, the readings of this instrument do not agree with these of the average-reading ones on all types of noise. For example, tests show that the reading of the quasi-peak-reading instrument is about five times the reading of the average instrument on automobile ignition interference measurements, other conditions being equal. That this is a step in the right direction is proved by the experience of users, who find that the average-reading instruments do not give readings which are at all indicative of the actual interference experienced with this type of noise. Many cases are on record of interference which in the loudspeaker of the radio receiver produced objectionable noise, but which on the meter of the noise measuring set produced no reading whatever. The quasi-peak instrument improves this condition greatly, although it is probable that on the more highly peaked types of noise its indications are still not quite proportional to the actual IEF. This is one of the conditions which must be left for future improvement when our knowledge of the relationships involved increases.

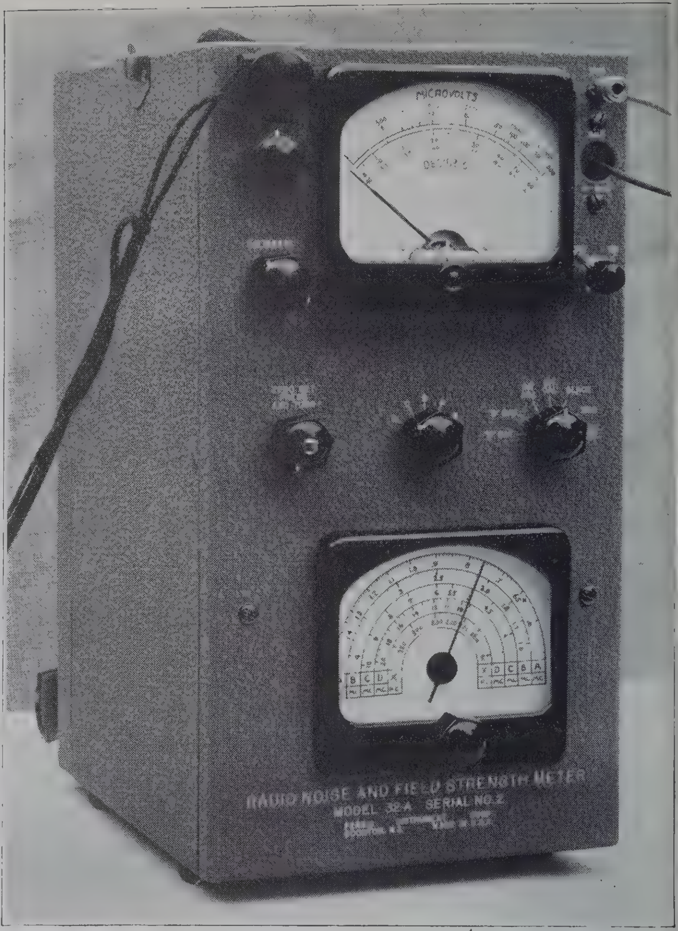


Fig. 3

The output indicator of the noise meter shown is not calibrated in the IEF units used for purposes of discussion in this paper, but in microvolts of noise impressed at the input terminals, so that the noise meter is a true voltmeter, or rather, microvoltmeter. The noise microvolts are stated in terms of a continuous wave unmodulated carrier which produces the same meter reading. This form of reference standard was chosen for its almost universal availability, ease of utilization, fundamental nature, and familiarity. The fact that noise voltages are read in microvolts retains a concept and a unit which are already familiar through their wide use in the measurement of transmitter voltages and fields, and permits direct comparison of noise fields with transmitter fields at a given location, on a single measuring instrument.

APPLICATION OF FREQUENCY MODULATION TO RADIO TRANSMISSION

By C. B. FISHER, Northern Electric Company

Summary

The growing interest in frequency modulation and the probability of its wide use in the near future makes a text-book presentation of the topic of some value. The purpose of this paper is to cover theoretical reasoning and calculated results for a radio circuit employing frequency modulation, in a simpler manner than has been followed in previous papers and to show some practical circuit details. Prior publications on this subject are briefly summarized and the mathematical basis of a frequency-modulated transmission is outlined. The transmitter problems are discussed and a simple method is suggested to obtain frequency modulation. The receiver problems are described with curves of typical circuit performance and curves are also shown for the signal-to-noise ratio under various conditions and in comparison to amplitude modulation. A brief survey is made of the probable usefulness of this type of transmission. A bibliography is included.

Introduction

A carrier wave of sinusoidal form and unvarying amplitude, frequency and phase constant is widely used in radio circuits but transmits no information until one of its constants is modulated*; hence arises amplitude modulation, frequency modulation or phase modulation. The phenomenon of amplitude modulation is well and widely understood and phase modulation does not concern us here but it is felt that there is now overdue a simple and concise treatment of the subject of frequency modulation. A number of articles on various aspects of this subject have been published since Carson's analysis in 1922 and a list of these with a brief summary of each is given at the end of this paper.

Mathematical Basis

An amplitude-modulated wave of unity carrier amplitude may be represented by:

$e = \cos \omega_c t\,(1 + M \cos w_a t)$ Where $\omega_c = 2\pi f_c$ and $\omega_a = 2\pi f_a$,

f_c and f_a being the carrier and modulation frequencies respectively and M the modulation factor. Such a wave may also be considered as made up of three components of constant amplitude and frequency; a carrier wave and two sidebands:

$$e = \cos \omega_c t + \frac{M}{2} \cos (\omega_c + \omega_a)\, t + \frac{M}{2} \cos (\omega_c - \omega_a) t.$$

A frequency-modulated wave, on the other hand, consists of a carrier wave of constant amplitude which varies in frequency above and below the value of f_c, by some amount f_d, this variation taking place f_a times per second. Hence the expression for a frequency-modulated wave of unity amplitude is:

$$e = \cos \left(\omega_c t \left(1 + \frac{f_d}{f_c} \cos \omega_a t\right) \right)$$

At first glance it might be thought that the frequency-modulated wave would occupy only the band of frequencies between $(f_c - f_d)$ and $f_c + f_d)$. This can be shown to be incorrect; it is found that the band occupied is always wider than this range and depends on f_a as well as f_c and f_d. Actually the wave may be considered as being made up of a carrier wave and side-bands. The side-band band components may be calculated by expanding the above equation in an infinite series, as follows:

$$\begin{aligned} e = {} & J_o \cos \omega_c t \\ & - J_1 \cos (\omega_c - \omega_a)\; t + J_1 \cos (\omega_c + \omega_a) t \\ & + J_2 \cos (\omega_c - 2\omega_a) t + J_2 \cos (\omega_c + 2\omega_a) t \\ & - J_3 \cos (\omega_c - 3\omega_a) t + \ldots\ldots\ldots\ldots \end{aligned}$$

That is, the side-band components have relative amplitudes denoted by the J's, and are infinite in number, spaced equally in frequency by an amount equal to the modulation or audio frequency, on both sides of the carrier. The J's are found to be Bessell's functions of the first kind, of the order indicated by the subscripts, the argument in each case being the ratio:

$$m = \frac{f_d}{f_a}$$

In actual cases it is found that the J's fall off rapidly in value for components having frequencies outside the bands $(f_c - f_d)$ to $(f_c + f_d)$ or $(f_c - f_a)$ to $(f_c + f_a)$, whichever is the greater. In Figure 1 are shown the sideband components in a frequency-modulated wave for a number of values of m. In each case the unmodulated carrier amplitude is 100. It is noted that only a few components of appreciable amplitude have frequencies outside the band $(f_c - f_d)$ to $(f_c + f_d)$ when m is greater than unity. It is unlikely that a commercial telephone transmission system would use values of m greater than 24, where f_a is the highest transmitted audio frequency, so that the data of Figure 1 may be considered to include most cases in practice.

Production of Frequency-Modulated Waves

Armstrong has described a useful method of causing linear frequency modulation. A carrier voltage derived from a crystal oscillator is shifted in phase an amount proportional to the amplitude of the modulating wave and inversely proportional to its frequency. A maximum of 30 degrees shift is employed with a carrier frequency of the order of 100 kilocycles. By a series of stages, frequency multiplication and frequency subtraction are carried out until a carrier of the order of 40 megacycles frequency, with a deviation of the order of 200 kilocycles, is finally radiated. The greatest skill is required in the design of these stages to effect symmetrical modulation free from noise and distortion. Other methods have been used, and are referred to in the bibliography.

As an additional method which appears to have important practical advantages, the present writer suggests a modification of an arrangement described by

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*"Modulate: To inflect or adapt, as the voice or sounds; to vary by some law of unity or beauty."

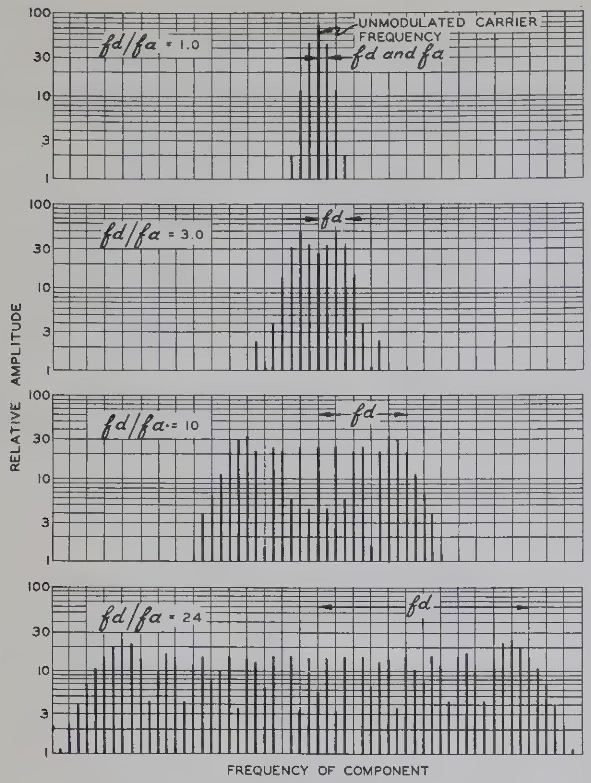

FIGURE 1. Sideband components in a frequency-modulated wave, for various ratios of carrier deviation to modulation frequency. The unmodulated carrier amplitude is 100, and components having amplitudes of less than unity exist in each case, but are now shown.

Travis, which has been widely used in commercial superheterodyne receivers, where automatic control of the oscillator frequency is desired*. A simplified circuit is shown in Figure 2. A triode is connected in a Colpitts oscillator circuit, a small resistance is included in the tuned circuit, and the voltage across it is led to the grid of a control triode, to which the audio-frequency modulating wave is also applied. The control tube is operated so that its mutual conductance varies with the instantaneous value of the audio voltage. The plate and cathode of the control tube are connected respectively to the plate and cathode of the oscillator tube and hence the control tube introduces a voltage across the tuned circuit 90 degrees out of phase with that generated by the oscillator tube. The magnitude of this voltage and hence the shift in oscillator frequency which it causes, is dependent on the instantaneous value of the modulating wave. This circuit provides a simple method of achieving large values of frequency modulation with normal oscillator circuits and little multiplication. Where it is necessary to have the unmodulated carrier frequency accurately controlled, this may be done by obtaining the bias voltage for the control tube from a discriminator circuit somewhat similar to that described by Travis but which uses crystals in the tuned circuits.

An experimental oscillator has been made up with the circuit of Figure 2 using two type 6J5 tubes and operating at 5 megacycles. The curve of Figure 3 shows

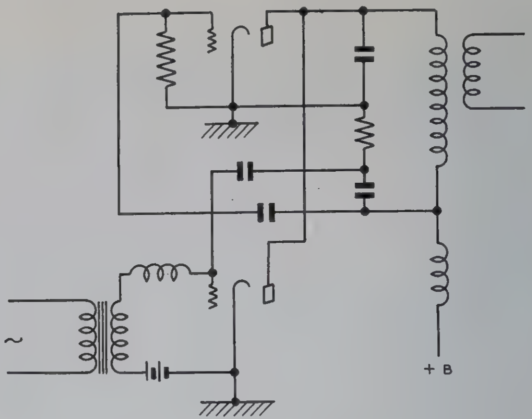

FIGURE 2. Circuit of frequency-modulated oscillator, with contro tube.

the frequency deviation against the bias voltage on the control tube and indicates that the swing is linear over a wide range of frequency.

The remainder of the frequency-modulated transmitter is quite conventional and requires only suitable broadening of the tuned circuits. Since the output stages handle a wave of constant amplitude they operate at high efficiency and a striking saving may be effected over equivalent amplitude-modulated transmitters. Figure 4 shows a comparison of a frequency-modulated transmitter and three types of amplitude-modulated transmitters, in regard to several factors which influence cost in the highpower stages. It is seen, for equal tube, power, and cooling capacity, that the frequency-modulated transmitter develops considerably more carrier power than do the amplitude-modulated transmitters.

Transmission of Frequency-Modulated Waves

Crosby and Armstrong have each reported on extensive experience with transmission conditions. Armstrong's work was carried out with carrier frequencies of 41, 44 and 110 megacycles and frequency deviations of 25, 100, 200 and 500 kilocycles, at distances of ½, 4, 60, 65 and 85 miles. He reports excellent reception on all circuits, with complete absence of distortion of any kind, although severe fading occurred on the ½,

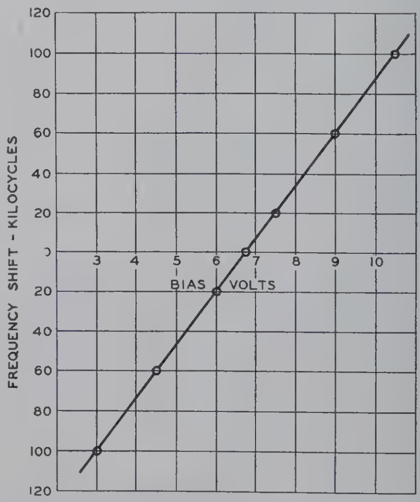

FIGURE 3. Frequency deviation of the oscillator circuit of Figure 2 for varying bias of the control tube. Unmodulated carrier frequency is 5 megacycles.

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*Since this was written a similar circuit has been suggested for use in a phase-modulated transmitter. See Ref. 13.

TYPE OF TRANSMITTER	TUBE CAPACITY	PLATE INPUT POWER AT FULL MODULATION	PLATE INPUT POWER AT ZERO MODULATION	MAXIMUM COOLING CAPACITY REQUIRED
CONVENTIONAL LOW-LEVEL AMPLITUDE MODULATION	400 KW	450 KW	300 KW	300 KW
CONVENTIONAL HIGH-LEVEL CLASS B AMPLITUDE MODULATION	375 KW	250 KW	160 KW	100 KW
LOW-LEVEL AMPLITUDE MODULATION WITH HIGH-EFFICIENCY AMPLIFIER	225 KW	225 KW	150 KW	75 KW
FREQUENCY MODULATION	100 KW	150 KW	150 KW	50 KW

FIGURE 4. Relative transmitter capacity, using various methods of operation, for a carrier power of 100 kilowatts, capable of complete modulation. Tube ratings shown are continuous class C output. The assumption is made in each case that a tube of exactly the required rating is available.

4 and 85 mile circuits. Crosby reports on a circuit from New York to California, operated on 9, 13.7 and 18 megacycles, with a frequency deviation of 6 kilocycles. Severe carrier fading was encountered, with fading and non-linear distortion generally rendering the circuits nearly useless. He hence concludes: "On circuits where multipath transmission is encountered, frequency modulation is impracticable". It is thought that this conclusion would be seriously modified if a larger deviation of frequency had been used.

Reception of Frequency-Modulated Waves

A frequency-modulated transmission may be received by a usual type of antenna and amplified in the usual manner, if some attention is paid to suitable broadening of the tuned circuits through which it is to be passed but evidently a rather special detecting or demodulating device is required. The simplest method is to use a passive network to give the wave an amplitude modulation corresponding to its frequency modulation and then detect this wave in normal rectifier circuits. In earlier receivers the conversion device was a de-tuned high-Q circuit but this gives linear performance for only a small deviation. For better performance a number of types of networks have been designed. Excellent results may be obtained from a circuit which is series-resonant near the unmodulated carrier frequency, fed from a source of relatively high resistance. Such a circuit and curves of its performance are show in Figure 5.

It is desirable that the receiver should respond to frequency modulation only, and should give a negligible response to amplitude modulation. This type of performance reduces the response to atmospheric and other noise picked up with the signal, which has the characteristics of a carrier with large amplitude modulation and comparatively small amounts of phase and frequency modulation Freedom from response to amplitude modulation may be obtained by using two circuits similar to the one shown in Figure 5, but having reversed slopes, and combining their outputs so that the components due to frequency modulation are additive, while those due to amplitude modulation cancel one another. Other detector circuits to achieve the same result are readily devised. It should be noted that detector circuits of this sort give freedom from disturbance in the output due to amplitude modulation nearly up to the point of zero carrier (that is, 100% negative modulation) but beyond this point the detector output involves components due to amplitude modulation.

Balanced detector circuits will probably prove to be of minor value in future designs for eliminating amplitude modulation, as this result can usually be achieved satisfactorily by means of an I-F stage designed to overload at a low carrier input, so that its output remains constant for all carrier levels above this value. The circuit of an amplitude limiter of this sort and a curve of its performance in a typical receiver are shown in Figure 6. It is seen that for carrier voltages in excess of 5 microvolts amplitude modulation is reduced by a factor of about 105 db. A limiter circuit of this sort can bring about reduction of amplitude modulation down to about 100% on negative peaks, and somewhat less than this at low carrier levels.

An important improvement in receivers for frequency modulation has been described by J. G. Chaffee. A superheterodyne circuit is employed and part of the audio output is used to frequency-modulate the local oscillator, out of phase with the modulation of the incoming wave. The net result is that noise and distortion generated subsequently to the oscillator are reduced and the frequency deviation in the I-F amplifier is also reduced below the deviation of the transmitted signal. This arrangement obviously offers the receiver designer a useful tool for obtaining satisfactory results, and simplifies the I-F amplifier and conversion circuit designs. The receiver oscillator circuit need not be complicated, as may be seen from the circuit of the modulated oscillator of Figure 2.

Response to Noise

Frequency modulation will give considerably better values of signal-to-noise ratio than will amplitude modulation under suitable conditions, for the same transmitter equipment. In Figure 4 the relative transmitter capacities are shown in detail, and as an overall estimate it seems fair to say that a high-power frequency-modulated transmitter will develop some 3 db. more carrier power than an amplitude-modulated transmitter of the same cost. In addition to this, an important gain in signal to noise ratio may be achieved at the receiver. Complete studies of the improvement due to the receiver have been published by Armstrong and Crosby, showing that calculated and observed results are in good agreement and the following discussion is a much abridged form of that given by Crosby in ref. 11 of the bibliography. The case of greatest practical importance is the comparison of a frequency-modulated system with an amplitude-modulated system, where the transmitters

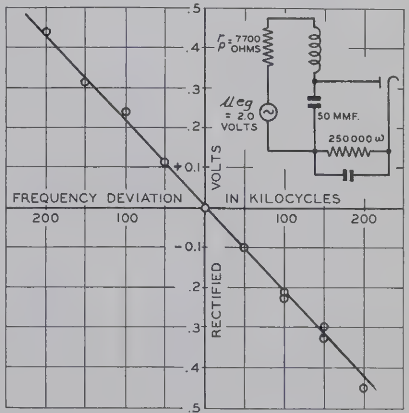
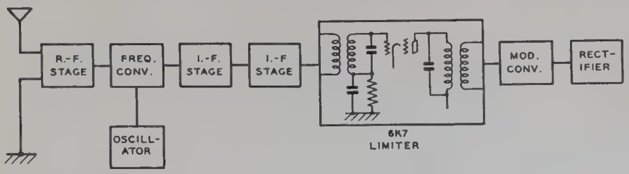


FIGURE 5. Performance of typical modulation detector circuit. Unmodulated carrier frequency is 500 kc.



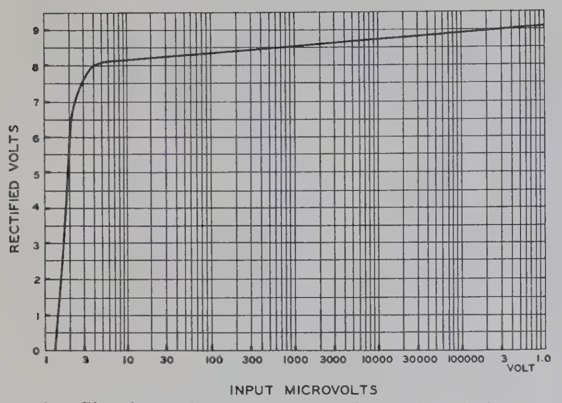


FIGURE 6. Circuit performance of receiver with limiter stage for reducing amplitude modulation.

have equal carrier power, the amplitude modulation is held at 100%, the ratio of frequency deviation to audio band width is **m**, the noise voltage is small in comparison to the signal voltage and is uniformly distributed in frequency throughout the band. Under these conditions the signal-to-noise voltage ratio will be better in the frequency-modulated system by a factor of $\sqrt{3}\,\mathbf{m}$. For a value of **m** of 20, which is readily obtained, the total improvement due to transmitter and receiver with frequency modulation hence becomes of the order of 34 db., or the equivalent of an increase in transmitter power of 2400 times.

For impulsive types of noise, which are of interest at the higher carrier frequencies, the improvement due to the frequency-modulated receiver rises slightly, to a value of **2m**. The equivalent increase in transmitter power under the conditions described above hence rises from 2400 to 3200 times.

For ratios of peak carrier voltage to peak noise voltage near unity the analysis becomes burdensome, but Crosby has published calculated curves for values of **m** of 1.0 and 4 and Armstrong has published measured data for **m** = 10. This data has been used to make up Figure 7. These curves do not include the gain at the transmitter. It is noticeable that the higher deviation ratios give their excellent performance only for low noise conditions. If the unmodulated carrier to peak noise ratio approaches unity, a deviation ratio near unity will, however, show an improvement over a fully amplitude modulated transmission. Noise measurements for carrier to noise ratios near unity are somewhat unreliable due to widely different results in this region with noise of different characteristics and with different amounts of modulation of the carrier frequency.

Future Use of Frequency Modulation

It is difficult for an impartial ovserver of the broadcast services of Europe and North America to escape the conclusion that their status is highly unsatisfactory and shows no visible signs of improvement. This has been brought about by the large number of stations transmitting in the long and medium wavebands. Even the relatively few so-called clear channels suffer from interference from high power transmissions on nearby channels. In any case, it is not possible to give reasonably good service, both day and night, to an area made up of rural and urban communities of more than a few thousand square miles in extent, from a single transmitter, whatever its power may be. These conclusions, which are not original or new, lead one to look for some solution of the problem more satisfactory than that under which we labour at present. We must first assume that conditions of national emergency or some as yet unforseen changes in the attitudes of governments do not arise, so that it remains desirable to make available to each receiver in use a considerable number of technically satisfactory transmissions. We must further assume no great and fundamental improvement in receiver design is about to be achieved, such that with existing or more closely spaced frequency allocation, satisfactory reception is possible. No hint has been given publicly that such an improvement is near perfection, and fundamental studies suggest that it is unlikely that such an improvement is possible, although in the light of the history of frequency modulation one does not incline towards placing great value on negative conclusions of the theorists. Note that a general increase in transmitter power, whether due to new developments or not, will not improve the present situation appreciably, as present service areas tend to be limited by fading and interference rather than by noise.

In order to improve the situation we require a type of transmission in which, with reasonably high power, good night and day service can be given by a single station over a radius of 50 to 100 miles, in the absence of interfering transmissions. This performance is at least as good as is being obtained at present. Beyond this distance the signal strength must decrease rapidly, and must not at any distance rise to an appreciable value, under either day or night conditions. This requirement will eliminate the enormous areas over which the existing high-power medium and long-wave stations provide unsatisfactory service themselves, and prevent any other station on their frequency from serving those areas.

These requirements are very nicely met by transmissions about 40 megacycles in frequency. Transmitter and receiver design is well understood and presents no difficulties. Reliable signals can be laid down

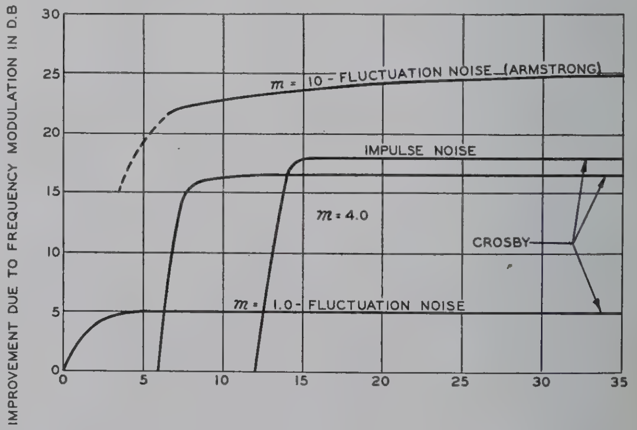


FIGURE 7. Improvement in signal-to-noise ratio due to frequency modulation for receiver only, as measured by Armstrong and Crosby, **m** is ratio of frequency deviation to audio band width. Modulation factor unity for amplitude-modulated carrier.

in the vicinity of the transmitter with comparatively low power, due to the low noise levels at these frequencies. Automobile ignition systems and high-frequency medical apparatus are the principal sources of noise, and these sources could be readily controlled. The high overland attenuation at these frequencies, and the slight reflections from the Heaviside and other layers, ensure that fading will be minimized and that the nuisance area of the station will not be much greater than its service area either night or day.

With the existing method of amplitude modulation the case seems very strong for a system of high-frequency moderately-powered stations using a limited number of frequency assignments, to deliver satisfactory signals to an area the size of North America, as against our present system. High frequency transmissions of this sort are well suited to the use of frequency modulation with large deviation ratios, and the enormous gains in transmitter cost and signal-to-noise ratio provide an additional improvement over the existing system. It thus appears that in practice a system of frequency modulation offers real advantages to the public. The transmitters and receivers which will be used on a wide scale system of this sort have as yet not been designed, much less built and installed. There is therefore no objection to introducing a new method of modulation based on obsolescence of existing designs or apparatus.

Between the day on which a change first appears to be advantageous, and the day on which that change is actually made, there may elapse a period of years, so that it is unwise to make predictions of the wide use of frequency modulation in the next few years. Considering, however, its undoubted value in specific cases, the unsatisfactory nature of the present broadcast services, the great apparent advantages of a system as outlined, and the active large-scale experimental work now in progress on frequency modulation, it seems reasonable to prophesy its extended use in the near future.

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THE OVERVOLTAGE TIMER AND AN EXAMPLE OF ITS APPLICATION TO THE MEASUREMENT OF RADIO INTERFERENCE

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Introduction

It is frequently desirable to study quantitatively a physical magnitude which is continually changing, for example, the sound pressure corresponding to speech or music, the field intensity of a distant fading radio transmitter, or the intensity of static or other form of interference in a particular radio receiver. Theoretically, a complete record of the variations of the magnitude may be made on a paper strip chart by means of a suitable recording instrument. Practically, however, such a record may not be very usable or satisfactory. It may contain much more information than is needed for the problem at hand and tedious analysis may be necessary for the extraction of the essential data. Indeed it is not uncommon to accumulate recorder chart faster than it can be interpreted or used. In many cases, therefore, an indicating instrument yielding data in a condensed and more directly usable form is preferable to a recorder.

The operational characteristics most desirable in an indicating instrument for any particular investigation inevitably depend on the nature of that investigation, just as the method of analysis which would be applied to the complete recorder chart would depend on the aspects of the data pertinent to the particular problem at hand. Since the automatic condensation of the complete information by the instrument may be accomplished in many different ways there are many kinds of indicating instruments designed for measuring continually varying magnitudes, each kind having its own sphere of usefulness.

Instruments indicating the root-mean-square value of a continually varying voltage or current have been much used in steady state a-c measurements. Their great utility results from the fact that an r.m.s. voltage or current has the unique and useful property of being proportional to the square root of the average power. It does not follow from this, however, that an r.m.s. instrument should be used for measurement in cases where power is not a primary consideration.

The ordinary d-c meter, when used to measure a varying voltage, indicates the average value as do some types of vacuum tube voltmeters. The average value is, from the mathematical point of view, a simple characterization of the varying voltage, and is frequently, therefore, a useful one. However, the average value is sometimes of little significance, as for example, in the case of waveforms having relatively high peaks of short duration.

For the study of vacuum tube amplifier overloading a maximum or peak value is most significant and so peak reading vacuum tube voltmeters have been much used for this purpose. They function very satisfactorily for the measurement of periodic or quasi-periodic waveforms. But for very erratic or randomly varying voltages the true peak value is of little significance because it exists so rarely and briefly. The value which is exceeded a given percentage of the time would be much more useful in many cases. The Overvoltage Timer[1] has been developed for use in making such measurements.

Three values, which can be measured with this instrument, corresponding to three specific percentages of the time, have been found particularly convenient and significant. One of these may be defined and named without hesitation. The value which is exceeded 50% of the time is called the "median", in accordance with well-established statistical terminology. The other two values have been called "quasi-maximum" and "quasi-minimum." There is as yet no firmly established usage with regard to the percentages of time to be assigned to these terms. The values of 5% and 85% respectively, noted later in this article, were adopted because they were well suited to the tests and instrument here described. It is not intended to imply any particular superiority of these values for general use. However, the concepts of median, quasi-maximum and quasi-minimum, while not original with the authors, have been found very useful in the work here reported and it is urged that these terms be considered for general acceptance and standardization.

The Overvoltage Timer

This instrument indicates the percentage of the time the instantaneous voltage impressed on its terminals exceeds in absolute magnitude, without regard to sign, a pre-determined threshold value. It is similar to an instrument described by H. O. Peterson of R. C. A. Communications, Inc.[2] He called the quantity measured "percent mark", referring to the percentage of the time the input to the telegraph recorder exceeded the value necessary to cause the recorder to register or "mark". Hence the instrument might be called a "percent mark meter". However, a name not connected so definitely with a specific use seems preferable. Although the device was developed primarily to evaluate the seriousness of interferences to radio reception, to call it a "Noise Meter" or an "Interference Meter" would not be sufficiently specific. The name "Overvoltage Timer" which has been chosen is by no means ideal but seems to have as much in its favor as any which has been considered. It is short enough to be convenient, specific enough to avoid ambiguity, and to some extent, at least, descriptive.

A circuit diagram of the Overvoltage Timer is shown in Figure 1. To the basic circuit shown by Peterson[3] has been added an audio amplifier stage and a full wave rectifier so that the instrument may be used on audio circuits instead of on d-c relay circuits. Two multiple function tubes, Types 85 and 79, have been used. Means have been included for adjusting the indicating meter scale and for adjusting and determining the threshold voltage. Heater power is obtained from a storage battery or from a 115 volt 60 cycle power line. Plate voltages are obtained from dry batteries included within the instrument. Since the drain on these batteries is so small that their life in the instrument is substantially equal to their shelf life and since the simple adjusting prodecure readily discloses when a battery should be replaced the use of batteries was found desirable in view of the complications which rectifier type of power supply would introduce.

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[1] U. S. Patent No. 2,079,064, C. M. Burrill, May 4, 1937.

[2] A Method of Measuring Noise Levels on Short Wave Radiotelegraph Circuits, Proc. I.R.E., Vol. 23, No. 2, p. 128, Feb. 1935.

[3] Loc. cit.

The finished instrument is pictured in Figure 11. Two of these instruments have been built, one for our own use and one for use by R.C.A. Communications.

The heart of the device consists of a two stage d-c amplifier adjusted to have the unusual limiting characteristic shown in Figure 2. In this figure the ideal curve is shown in the solid line while the dotted line shows the curve actually obtained through the use of the two triode units of the Type 79 tube. Practical tests have indicated that this degree of approximation to the ideal is quite satisfactory.

When a varying d-c voltage of the correct polarity is impressed on such an amplifier, the output current consists of substantially rectangular pulses. Whenever the input voltage is less than the threshold value, the output current is practically zero; and whenever the input voltage exceeds the threshold value the output current is substantially constant at a limiting value. The duration of each pulse is equal to the time interval during which the input voltage exceeds the threshold value. The integral of the output current is, therefore, proportional to the time the input voltage exceeds the threshold value. In this instrument the practical accomplishment of the integration is obtained by using a slow acting d-c indicating milliammeter.

In order to obtain an instrument having a high input impedance, suitable for measurements on a-c circuits of poor regulation, the d-c amplifier is preceded by an 85 tube, constituting a triode a-c amplifier, transformer coupled to a full wave diode rectifier. A 500,000 ohm voltage divider or attenuator, adjustable in 19 steps of 2.5 db each, is used in the grid circuit of the triode in order to adjust the threshold value of the instrument. The dial of this attenuator is calibrated to indicate the value of the threshold voltage in db above a reference level of one volt. One input terminal is grounded to the instrument case, and a blocking condenser is inserted in the other input lead. Thus the instrument is not affected by a d-c component in the voltage measured, nor will it affect the usual audio frequency circuit to which it may be connected, for its input impedance is greater than 0.5 megohm over the entire audio frequency band.

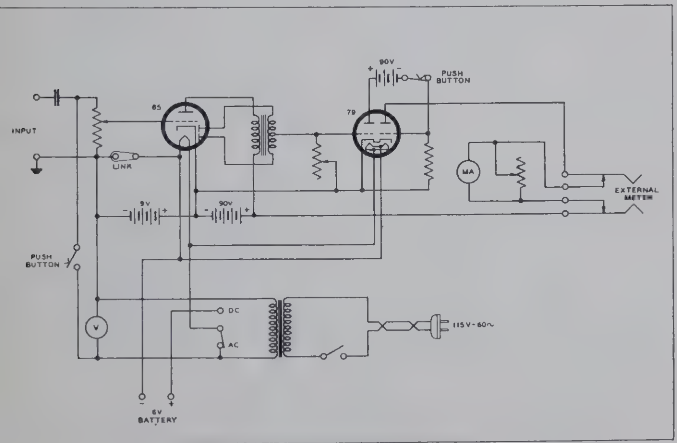

Fig. 1

The diode load resistor is made variable in order to adjust the sensitivity of the instrument to a standard value. The indicating instrument is a Weston Model 301 milliammeter having a slow movement (natural period about 1.5 sec.). It is over-damped, partly as a result of shunting it to adjust its sensitivity. A linear scale is provided reading from zero to 100 percent, corresponding to the percentage of the time the input voltage exceeds the threshold value. A jack is provided so that an external meter having any desired characteristics may be substituted for the internal meter and its shunt.

Adjustment of the Instrument

The first step in the use of the instrument is to adjust the sensitivity of the output meter by means of its shunt so that the limiting value of output current corresponds to full scale or 100%. This limiting current is the plate current of the second triode section of the 79 tube for zero grid bias, corresponding to complete cutoff of the first triode section and hence to an input voltage continuously greater than the given threshold value. For purpose of adjustment it is easier to reduce the plate current of the first triode section of the 79 tube to zero by opening the plate circuit than by biasing it to cutoff. Thus the adjustment is made by opening this plate circuit with a push button and then adjusting the shunt until the milliammeter reads 100%.

The next step is to adjust the sensitivity of the instrument so that the threshold voltage has the desired value. To accomplish this it is convenient to use a test signal of known amplitude and waveform. Where 60 cycle power is available it doubtless will be used to supply heater current for the tubes and if the heater voltage is of good sinusoidal wave form, it may be used as such a test signal. Accordingly a push button is provided for impressing the heater voltage on the input terminals. The

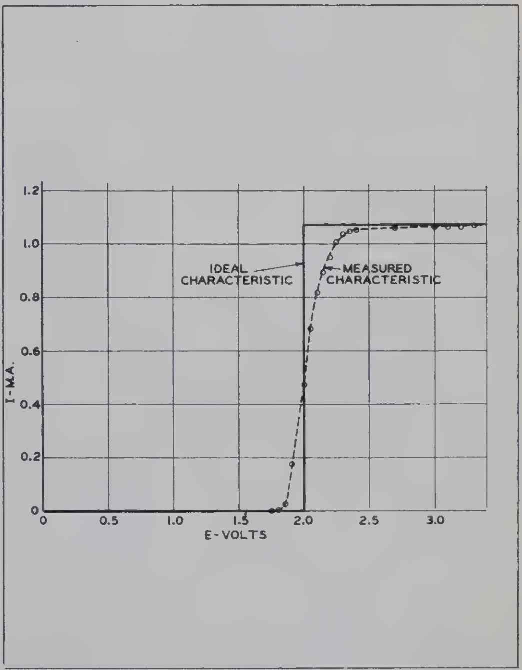

Fig. 2

r.m.s. value of this voltage is read by means of a voltmeter, and from this reading, assuming sinusoidal waveform, the percentage of the time this voltage exceeds any given threshold value can be calculated from the expression given below.

Let E_o = a given threshold voltage

$e = E_{max} \sin \omega t$ = impressed voltage

$E_{rms} = \frac{1}{\sqrt{2}} E_{max}$ = effective value of e

M = the percentage overvoltage, i.e. the percentage of the time during which e is greater than E_o.

Then it can be shown that

$$\frac{E_o}{E_{rms}} = \sqrt{2} \cos \frac{\pi M}{200}$$

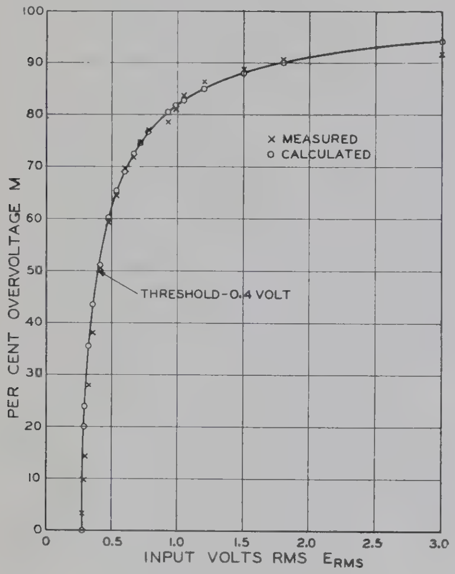

Fig. 3

The calibration of the Overvoltage Timer may be checked, using any known sinusoidal test voltage by means of this relation. Such a check is shown in Figure 3 in which the crosses represent actual readings of the output meter and the circles represent calculated points. The calculation assumed that the instrument characteristic was ideal as indicated by the solid line in Figure 2 and that the voltage was sinusoidal. The coincidence of measurement and calculation shows that both assumptions were sufficiently accurate for all practical purposes and that the actual instrument characteristic is sufficiently near to the ideal.

In checking the sensitivity of the instrument, that is the absolute magnitude of the threshold voltage, using the 60 cycle sinusoidal heater voltage, the following procedure is convenient. First, set the input potentiometer so as to indicate a threshold of 15 db above one volt for which E° is 5.62 volts. E_{rms} is then read on the voltmeter and the value of E°/E_{rms} computed. Then from the equation already given the corresponding value of M is found. The heater voltage is then impressed on the input of the instrument using the push button provided, and the diode load resistor is adjusted until the output meter reads the correct value of M. In order further to simplify the making of this adjustment a range of values of M as a function of E_{rms} for $E_o = 5.62$ volts (15 db) may be computed, plotted and used.

An Application to Interference Measurement

The Overvoltage Timer has been used in connection with a recent study of radio interference in which a small universal fan motor and an electric razor were used as the sources of interference. The fan motor used the conventional commutator of relatively few segments and the razor was driven by a motor of the cam-operated contact variety.

In making such interference measurements as these the question always arises as to what type of output meter to use. Should it be a peak reading type or an r.m.s. type, or should it have some other characteristic? It is not the contention of the authors that the Overvoltage Timer is the perfect output meter for this purpose or that a single measurement made with it will tell all about an interfering wave. It is felt, however, that a quantitative knowledge of the relative roughness or smoothness of a complex wave should be very helpful in classifying it as to its nuisance quality. The ability of the Overvoltage Timer to indicate when an interfering wave has a relatively small number of very high peaks or a fairly high amplitude of almost continuous noise background should aid greatly in correlating electrical measurements with the subjective ear response to the interference. The authors, therefore, feel that this meter should be more useful than either peak or r.m.s. meters for noise measurement since it gives more information about the wave shape than do either of these other types of meter.

The tests here reported were conducted with a radio receiver, the Overvoltage Timer, a cathode ray oscillograph and a test signal generator, all located within a double shielded test cage. A.C. power was fed into the cage through a two stage filter so as to avoid the possibility of interference reaching the receiver over the supply line.

The source of interference under test was situated outside the cage and was connected to the standard test network which has been established for the testing of interference creating devices by the Joint Coordination Committee on Radio Reception of the Edison Electric Institute, the National Electrical Manufacturers Association and the Radio Manufacturers Association. The receiver input transformer primary connections were brought out of the cage through shielded wires and these were arranged so they could be connected across the "line-to-line" or "line-to-ground" test terminals of the network or alternatively to the signal generator output. Although the signal generator was situated within the cage, its output was brought out through a shielded lead so that the receiver input circuit leads, capacitance, etc. would not be altered in switching from interference source to signal generator source. Figure 4 shows the test set up.

The automatic volume control circuit of the receiver was made inoperative and in its place a manual control of the receiver r-f and i-f amplification was substituted. The output of the receiver was connected both to the Overvoltage Timer and to the oscilloscope so that, for check purposes, output waveshape might be observed.

The test procedure was as follows:

1. The receiver was tuned to the frequency at which a test of the interference was desired. The receiver input was connected across the test network at the

desired points. The receiver tone controls were set for maximum audio frequency range.

2. The a-f gain of the receiver was adjusted to as high a value as possible without introducing a degree of hum or hiss which would interfere with the measurements.
3. The interference source was turned on.
4. The receiver r-f and i-f gain control was adjusted to produce a median reading (50%) on the Overvoltage Timer, the attenuation of the latter being set for a threshold of 15 db above 1 volt. This was a convenient median value for the measurements and was well within overload limits of the receiver.
5. By use of the oscillograph a visual check was made to be sure that, at the above setting of receiver sensitivity, the interference was not overloading the a-f circuit of the receiver.
6. With all other ajustments untouched, the attenuator of the Overvoltage Timer was then shifted to the necessary settings to obtain quasi-minimum (85%) and quasi-maximum (5%) deflections of its meter and these attenuator settings were recorded.
7. With the receiver sensitivity and Overvoltage Timer set as described in (4) the interference source was turned off and the input to the receiver was switched from the interference network to the output of the signal generator. This generator was of the conventional type and during these tests it was modulated 30% with 400 cycles. The signal generator output was then adjusted to give a median reading of the Overvoltage Timer and this output of the generator was recorded.

This gave a measure of the interference in terms of the r-f signal modulated 30% with 400 cycles which would give a median setting of the output meter attenuator equal to that produced by the interference. If desired, other adjustments of the signal generator could be determined and recorded which would give the same quasi-minimum and quasi-maximum attenuator settings as had the interference. In general, however, the signal generator value for median settings, plus the quasi-maximum and minimum meter attenuator settings made using the interference source, gives an adequate idea of the relative amplitude of the wave and its degree of subjective ear disturbance.

A few examples of interference curves obtained during tests of the two sources of radio interference mentioned above will be of interest at this point. The graphs of Figure 5 represent average values for the Overvoltage Timer measurements made on the fan motor and razor when operating from either d-c or a-c current. From these graphs the following general conclusions can be drawn:

1. The occasional peaks produced by the razor, as indicated by the quasi-maximum (5%) values, have higher amplitude than those from the fan.
2. The occasional peaks found on the short wave band are worse than those in the broadcast band.
3. The steady background noise on short waves, as indicated by the quasi-minimum (85%) values, has somewhat greater amplitude than on the broadcast band.

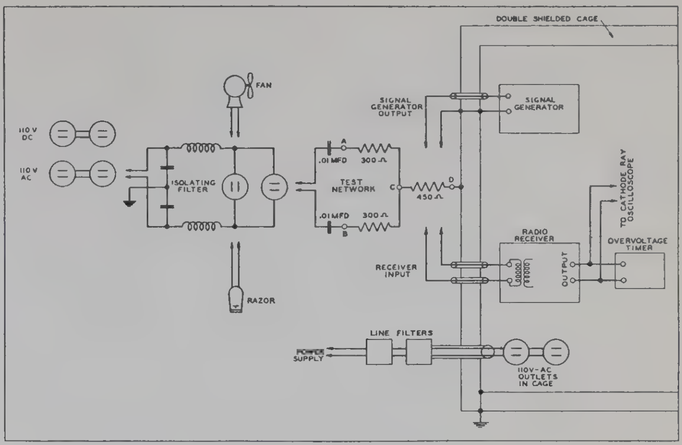

Fig. 4

To study further the problem of analyzing these curves let us examine two representative examples as shown in Figure 6. The solid curve shows noise from the razor under certain conditions of test while the dashed curve shows the noise from the fan motor. These are not given as representative of an average difference between these two devices but rather to show somewhat extreme differences of interference wave characteristics for these two interfering devices. The solid curve shows evidence of having considerably higher amplitude of occasional peaks, judging by the high quasi-maximum value, than does the dashed curve while its more nearly continuous background appears to be of lower amplitude (note low quasi-minimum setting) as compared with that indicated by the dashed curve. It is of interest to note that of the two types of interference giving the curves shown in Figure 6, the one represented by the solid curve was very noticeably more annoying to the listener than the one shown by the dashed curve.

As an example of still more extreme conditions we might have a case of line noise in an apartment house having a d-c operated elevator and various household devices operating on the line. Such a line might give a noise curve shaped somewhat like the dashed curve of Figure 7. Here the occasional quite violent clicks from the elevator motor contactors would result in the very high reading for a very small percentage of the time while the background of more or less continuous noise from miscellaneous other household devices is shown by the curve approaching a steady value of low amplitude for a high percentage of the time. As an antithetical case, the solid curve of Figure 7 shows the locus of the meter readings when a sine wave is impressed on it.

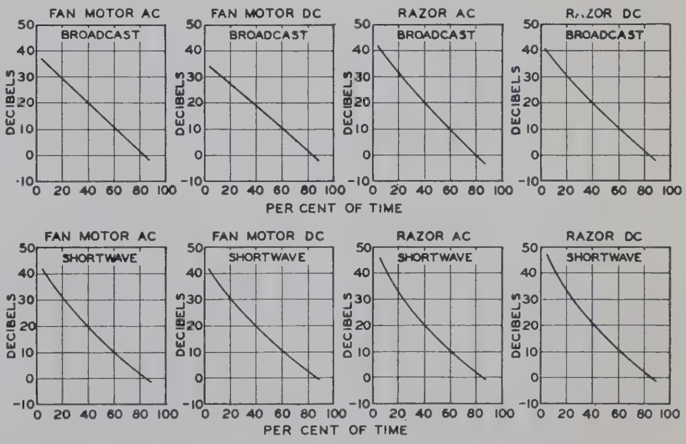

Fig. 5

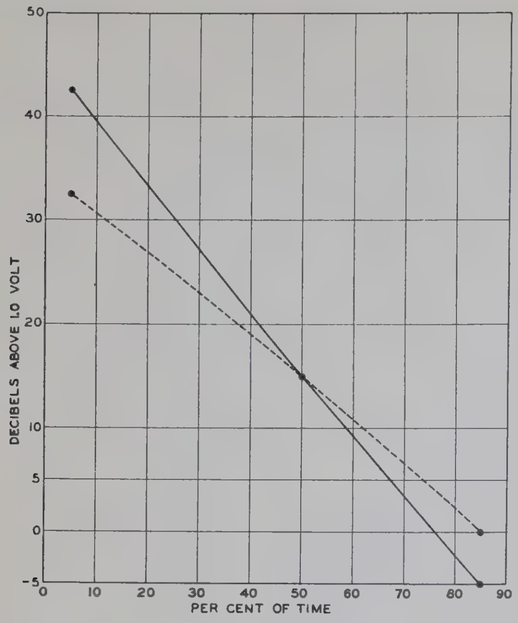

FIG. 6

As a result of brief study of these two curves, one may be tempted to draw the general conclusion that interference which produces an Overvoltage Timer curve approaching the shape of the solid curve of Figure 7 would be much less annoying than that producing a curve approaching the dashed curve shape. In the majority of cases this would probably be true. If, however, the curve has very low amplitude at, let us say, all percentages above 10 and only rises to high values at very small percentages of the time such a noise may be only moderately annoying. This would be the case with very infrequent loud clicks and an almost unnoticeable background of more continuous noise. Such interference might be less disturbing than that having a somewhat higher continuous level but lacking the occasional clicks. It is suggested that after some experience with various types of interference, the experimenter may acquire the ability to predict the degree of undesirability of certain types of interference by inspection of the curves they produce using the Overvoltage Timer.

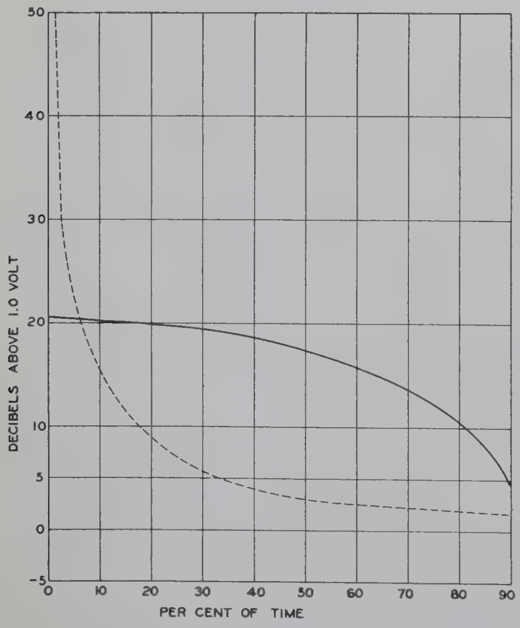

FIG. 7

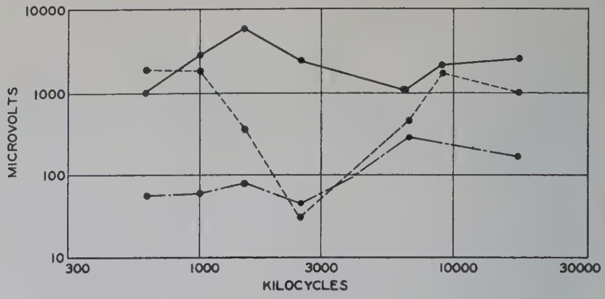

FIG. 8

For those readers who are interested in the radio frequency distribution of the interference of the two devices tested, the graphs of Figures 8, 9 and 10 are included. These show the equivalent median interference voltage (as ordinates) at various radio frequencies, measured under several test conditions as outlined in item (7) of the test procedure given above.

Figure 8 shows the characteristics of the interference from the fan motor when operated on a.c. The solid curve shows the interference voltage measured across the power line while the dotted curve shows that from line to ground. These two curves were measured with a line filter isolating the interference voltage source from the line, thus eliminating the effect of the line load on the measurement. The line-to-ground measurement was repeated with the filter removed, resulting in the dot-and-dash curve. The difference between the dotted and dot-and-dash curve shows the effect of the power line load in decreasing the interference voltage.

Figure 9 shows the results obtained by measuring the interference voltage developed by a connection between the fan motor frame and ground. A 200 $\mu\mu f$ capacitor was inserted between the frame and the input circuit of the receiver. Comparison of the solid and dotted curves shows the result of connecting capacitors of 0.01 μf from each brush of the motor to the frame. The effectiveness of this method of reducing interference from a motor of this type is well illustrated.

Comparison of the solid curve with the dot-and-dash curve of Figure 9 shows that the interference produced

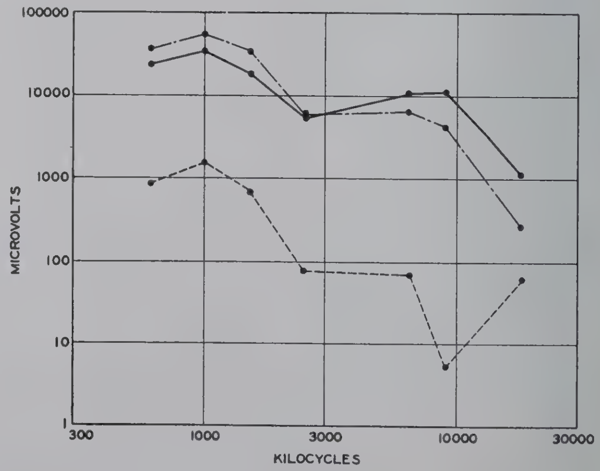

FIG. 9

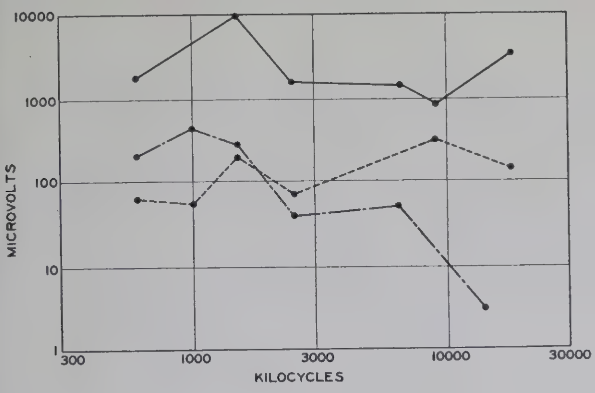

Fig. 10

by the motor is not greatly different when powered from a d-c instead of an a-c source.

Figure 10 shows results obtained in tests of the razor. The solid curve gives the line-to-ground interference voltage and the dotted curve the line-to-ground values. The values represented by the dot-and-dash curve attempt to show the voltage existing on the metallic parts of the device itself (similar to the frame-to-ground measurements on the motor). Since the razor frame was of insulating material, a wrapping of tinfoil was placed around it to give capacitance to the internal elements. This tinfoil was connected to the input of the measuring receiver. Judging from the low values of interference voltage obtained, it would seem at first glance that the tinfoil wrapping might have given insufficient capacitive coupling to the elements of the razor. If this were true it would be natural to expect this coupling to be more effective at the higher frequencies and that the curve of interference voltage would slope upward with increasing frequency. The fact that the curve does just the opposite leads to the belief that the capacitance provided by the tinfoil was low in reactance compared with the input circuit of the measuring receiver and that the values obtained are reasonably correct.

It should perhaps be mentioned that the development and the tests described in this article were not worked on jointly by the authors. The Overvoltage Timer was developed under C. M. Burrill's direction, while the particular application to interference measurement described was investigated under the direction of E. T. Dickey. Acknowledgment should be made of the assistance rendered by the following men: Mr. J. Epstein constructed and tested the preliminary sample of the Overvoltage Timer and Mr. H. R. Wege made the final mechanical design. Mr. C. E. Torsch prepared the set up for making the measurements on the fan and razor, carried out these measurements and tabulated the data resulting therefrom.

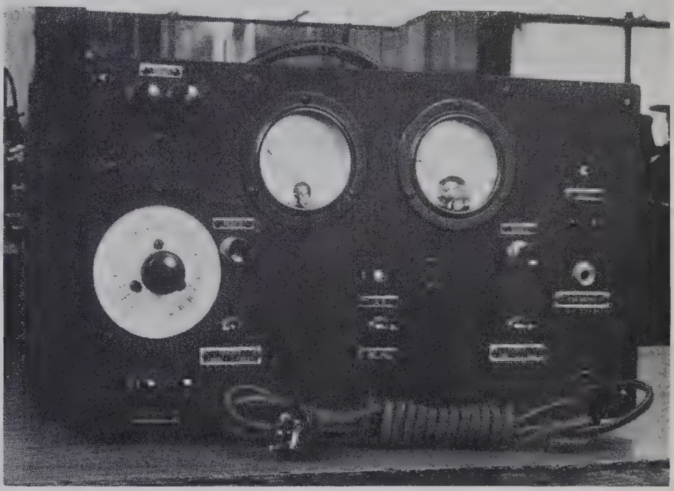

Fig. 11

THE RMA TELEVISION SYNCHRONIZING STANDARD— A SEMI-TECHNICAL EXPLANATION

By Albert F. Murray, Acting Chairman RMA Television Committee
Engineer in Charge of Television, Philco Radio & Television Corp.

Fourteen television standards, drawn by the RMA Subcommittee on Television Standards, approved by the RMA Membership, have been submitted to the Federal Communications Commission. These standards, listed on page 36, have been discussed in various radio publications.[1],[2] They are clearly stated and to the worker in this specialized field need no further explanation, with one exception—Standard T-111, Synchronizing.

The purpose of this article is to give, in response to requests, a semi-technical explanation of this standard.

It is well known that in cathode ray television the beam in the receiving tube is electrically synchronized at the start of each horizontal line and at the beginning of each picture (or field). The signals which accomplish this, together with picture signals (video frequencies) must be sent over a single communication channel. The way to do this is to interrupt the picture signal at the end of each line by a "blanking" impulse, which for a brief time completely cuts off the picture signal, allowing at this time the transmission of a horizontal synchronizing pulse. There follows a vertical blanking signal which cuts off the picture signal for a period of time, during which a vertical synchronizing signal of relatively long duration is transmitted. At the receiver, amplitude selection separates the picture signal from the synchronizing signal. The resulting synchronizing signal, free from picture signal, is passed through circuits which separate the horizontal from the vertical synchronizing pulses. This can be carried out by means of any of several available circuits.

Refer to Drawing T-111. At A we have a trace of a composite television signal. Reading from left to right, we find this is made up of a series of horizontal pulses located on the tops of the blanking signals. Between these is a wavy line indicating picture signal. Next, there is an interval of six equalizing pulses (explained later), followed by the vertical synchronizing signal containing five serrations. Following this is another equalizing pulse interval similar to the one already mentioned; next a continuation of horizontal synchronizing pulses located on top of the vertical blanking signal. After this we resume with picture signal, regularly interrupted by the horizontal blanking signals which are topped by horizontal pulses.

Diagram B differs from A in that it is shifted in time by 1/60 of a second, representing, therefore, the succeeding picture field. Note that the space between the leading edge of vertical blanking and the preceding horizontal pulse differs by .5H* in the two diagrams. This takes care of the difference in successive frames due to odd line interlacing.

Over the signal communication channel referred to above, information also must be transmitted regarding what is known as "picture black." This information is conveniently conveyed by fixing, in the modulating wave shown in T-111, a black level. This reference level corresponds to the height of the blanking signals as shown in the drawing. A signal corresponding to increasing picture brightness moves **downward** from this line in the direction of "maximum white." This, of course, is recognized as negative transmission. The picture signal can never swing above the black level, since "black" is obviously the lowest intensity of picture which need be transmitted. Notice that the carrier amplitude above the black level (20-25%), is reserved for synchronizing pulses. The remainder of the transmitter carrier amplitude is utilized, as required, for picture signal transmission.

Equalizing pulses are used before and after the vertical pulses so that the type of receiving circuit known as the integrating type, when synchronized vertically, will have an opportunity to interlace. The requirement is that the difference between the starting of the odd and even vertical synchronizing signal is equalized, that is, the same amount of electrical charge accumulates over the same period, whether an odd frame or an even field is being received. To accomplish this equalization it will be noted that equalizing pulses occur at twice the rate of the horizontal, for the same reason that the vertical signal is serrated at double frequency, explained below. The duration of the equalizing pulses is half that of the horizontal synchronizing pulses. This has been found in practice to be desirable.

If the vertical pulse was a single long continuous pulse, without serrations, there would be no steep wave fronts occurring at horizontal frequency, so that there would be nothing to maintain horizontal synchronization during the vertical pulse. A synchronizing axiom is that the horizontal pulses **must** be transmitted continuously. For this reason serrations are cut into the long vertical pulse, the steep wave fronts of which provide horizontal pulses of the proper spacing. The serrations are of double horizontal frequency because under these conditions the same kind of vertical synchronizing signal will serve for both odd and even fields.

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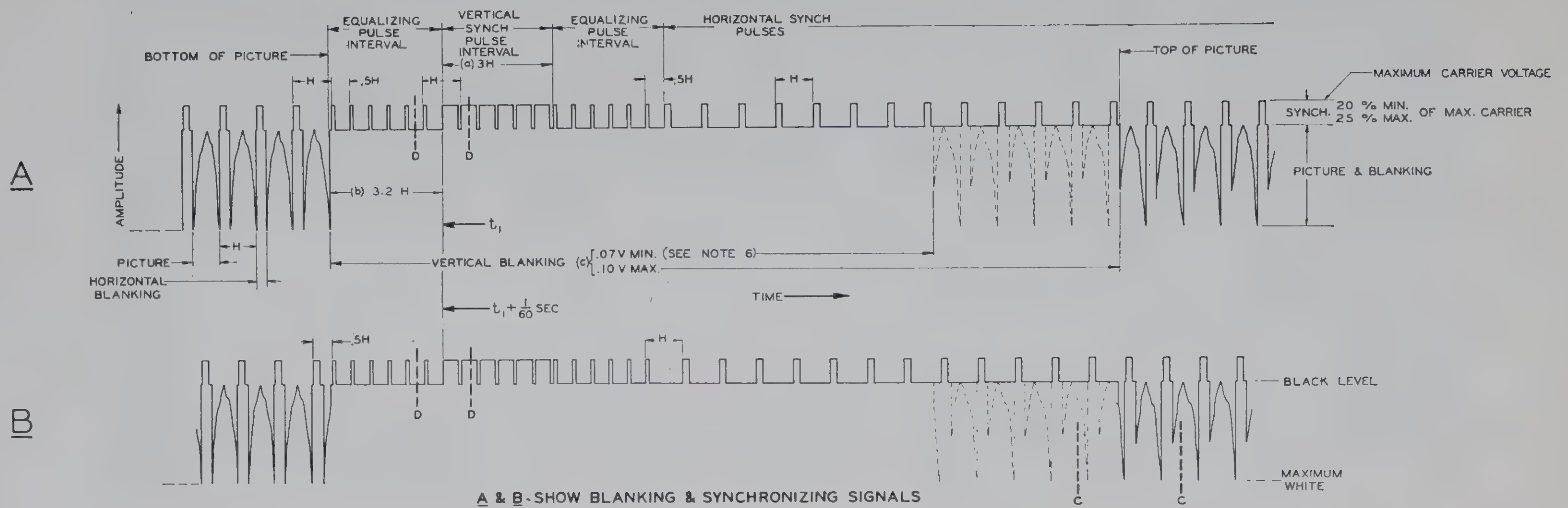
[1] RMA Complete Television Standards, by A. F. Murray, Electronics, July 1938, p. 28.

[2] RMA Recommends Television Standards, by A. F. Murray, Communications, Nov. (or Dec.) 1938.

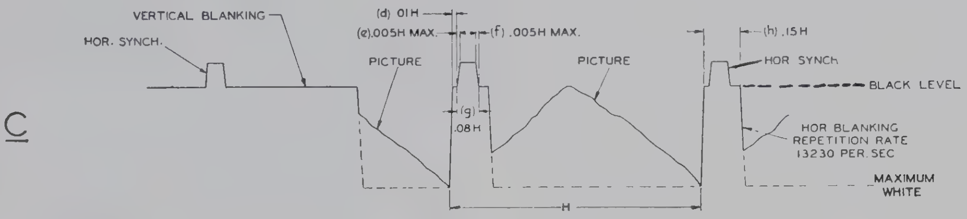
*"H" is proportional to the time from the start of one line to the start of the next line.

RMA STANDARD T-111
TELEVISION SIGNAL

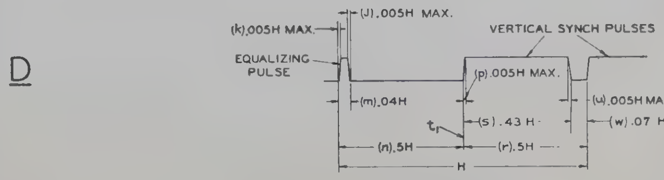
441 LINES, 30 FRAMES PER SEC., 60 FIELDS PER SEC., INTERLACED



A & B - SHOW BLANKING & SYNCHRONIZING SIGNALS IN REGIONS OF SUCCESSIVE VERTICAL BLANKING PULSES. (HORIZONTAL DIMENSIONS NOT TO SCALE. ALL DIMENSIONS ARE FROM BLACK LEVEL UNLESS OTHERWISE SPECIFICALLY INDICATED)



DETAIL BETWEEN C-C
DIMENSIONS TO SCALE



DETAIL BETWEEN D-D
DIMENSIONS TO SCALE

1 - DIAGRAM C SHOWS ENLARGED DETAIL VIEW OF SIGNAL IN VIEW B BETWEEN LINES C-C

2 - DIAGRAM D SHOWS ENLARGED DETAIL VIEW OF SYNCH. SIGNAL IN VIEW A BETWEEN LINES D-D

3 - H = TIME FROM START OF ONE LINE TO START OF NEXT LINE = 1/13230 SEC.

4 - V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD = 1/60 SEC. = 220½ H

5 - LEADING AND TRAILING EDGES OF BOTH HOR. AND VERT. BLANKING PULSES HAVE SLOPES (NOT INDICATED IN A & B) WHICH SHOULD BE KEPT AS STEEP AS POSSIBLE

6 - RECEIVER VERTICAL RETRACE SHALL BE COMPLETE AT END OF .07 V

JULY 12. 1938

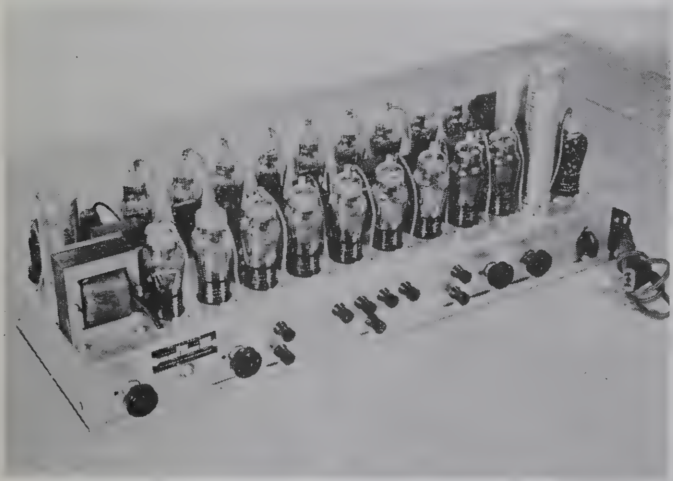
Questions and Answers

A few of the more often-repeated questions concerning the synchronizing standard are answered in the paragraphs that follow.

1. Q. What are the requirements for the horizontal pulse?
   A. The pulse must be placed on top of the blanking signal, set back from its leading edge, .01H, so that the necessary steep wave front of the pulse is not influenced by the slope of the banking pedestal. A steep wave front is needed for the horizontal pulse. A slope of only .005H is the maximum allowed. The same slope is used on the falling side of the pulse. The width of the pulse is maintained at .08H.
2. Q. What are the requirements of the vertical signal?
   A. It should have the same height as the horizontal. The vertical blanking pedestal which is not less than .07V nor more than .10V* in duration. The vertical pulse interval which has a duration of 3H, is placed at a distance of 3.2H from the leading edge of the vertical blanking signal. The leading and trailing edges of each pulse must be steep, the same steepness as specified for the horizontal pulses. The five serrations each have a width of .07H.
3. Q. What are the requirements of the equalizing pulses?
   A. In height these should be the same as the vertical and horizontal signals. Six precede and six follow the vertical pulse interval. The steepness of the sides corresponds to that of the horizontal and vertical pulses. The width is half that of the horizontal pulse, .04H. They occur at twice the frequency of the horizontal pulses.
4. Q. Why do not the equalizing pulses and the serrations in the vertical signal cause the horizontal synchronizing oscillator at the receiver to run at double speed?
   A. The usual type of synchronizing oscillator is not susceptible to synchronizing pulses except those arriving spaced approximately by the distance H.
5. Q. What determines the duration of the horizontal or vertical blanking signal respectively?
   A. The duration must be sufficient to allow the scanning spot to retrace its path to the beginning of the next line or picture field respectively.

Concerning General Considerations:

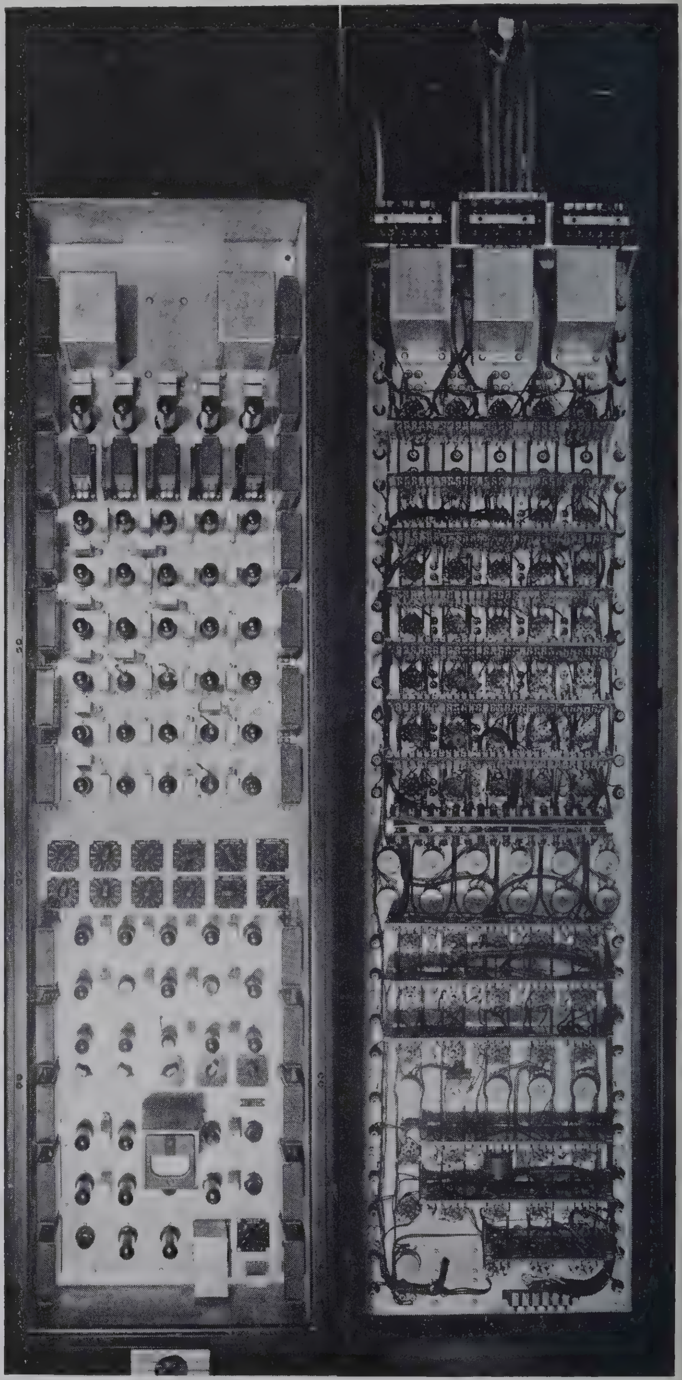
6. Q. How can the RMA Synchronizing Signal be generated?
   A. By synchronizing generators having fairly complicated circuits, usually of the multi-vibrator or other electronic type. Their output signals are rigidly related in frequency to 60-cycle power supply. The signal can be generated by specially designed A.C. generators resembling a Fessenden alternator. Rotating, apertured discs through which light beams shine into the photocells, with suitable auxiliary equipment, give good results.



Portable Television Signal Generator—(Courtesy Philco)
Incorporating low-power television transmitter for receiver testing, with either self-generated grating pattern, or picture signal derived from an external source.

7. Q. Was the RMA standard signal chosen as the result of carefully considered engineering experience, and is it practical?
   A. Yes, it was decided upon by the RMA Television Committee after considering and discussing the problem for more than two years. During this time various engineers of the Committee had experimented with other types of signal, including that which is standard in Great Britain.

(*Continued on page 35*)



(Front View, cover removed) (Rear View, door removed)
Synchronizing generator for broadcast station service having five outputs at 75 ohm impedance and four volts peak to peak.
1. Synchronizing pulses RMA T-111
2. Blanking pulses RMA T-111
3. Iconoscope blanking pulses
4. Special horizontal pulses for Iconoscope deflection
5. Special vertical pulses for Iconoscope deflection

(Courtesy RCA Manufacturing Co., Inc.)

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*"V" is the time from the start of one field to the start of the next field.

DIE CASTINGS IN RADIO APPLICATIONS

By W. W. Broughton Engineer, Technical Service
The New Jersey Zinc Sales Company

After the electronic and the purely electrical problems in the design of radio and related equipment have been solved, there still remain the hardly less important matters of structure or mechanical design. Yet the author is told that these latter considerations have been given relatively little consideration in the deliberations of your association, although their significance is doubtless fully appreciated.

When matters of structure and of individual mechanical parts of an assembly demand attention, the utility of the die casting cannot safely be overlooked. It ranks next to the stamping in importance in the production of many light assemblies and there are not a few instances in which its cost is even lower, both as to tooling and to production per piece. There are in addition several types of metal parts which cannot be duplicated with an economy approaching that realized when the die casting is employed.

Die castings are often produced with smaller tolerances, with fewer and less expensive machining and assembly operations, and with certain structural advantages not possible at an equally low cost by any other method that has yet been devised. Indeed, the use of die castings is justified not only on economic but on purely engineering grounds as well. Before illustrating this point by reference to specific examples, however, it may be well to first consider the more important alloys used for die casting radio and related parts and the properties which govern their selection.

Only those alloys based on zinc and on aluminum have proved of much significance to the radio industry. Of these the zinc alloys are much the more important since they account for some 80 to 90 per cent or more of the total number of die castings supplied to radio applications. As compared with aluminum alloys, the zinc base type of alloy costs less both per pound and per piece, is superior in most significant physical properties and especially in toughness (impact strength); is easier to cast, to machine and to plate; it has a negligible effect upon die life, and the dies required for the casting of zinc alloys usually costing less initially than those required for aluminum die casting. Additionally, in many instances the zinc alloy die casting can be produced in thinner sections, within closer dimensional limits and with a smoother finish than the aluminum type. Under these circumstances, almost the only places in radio applications in which aluminum can rationally be chosen in preference to zinc is where light weight is a primary consideration.

In the accompanying tables are given the composition and the more important physical properties of the zinc and aluminum alloys which have gained widest use. All these alloys meet A.S.T.M. specifications, but the limits as to constituents and impurities in the Zamak zinc alloys are held even closer than are required under these specifications. It is of great importance that only high purity, 99.99+%, zinc be employed in producing the zinc alloys, as otherwise the essential and very low limits with respect to tin, lead and cadmium content which has been set with excellent reasons be exceeded. This fact is well understood by reliable die casters and is frequently checked by them, as indeed, it should be and by purchasers of die castings as well.

Of the three most commonly used zinc alloys here listed the choice today usually rests between Zamak 3, which contains no copper and Zamak 5 which contains only 1% of copper. Zamak 5 is intermediate, in most significant properties, to Zamak 3 and Zamak 2, the latter containing 2.70% copper and having had widest use in recent years. The higher copper content produces a somewhat harder alloy and one having the highest tensile and compressive strength, but its impact strength is initially somewhat lower and is reduced rapidly with aging, whereas Zamak 3 and Zamak 5 alloys retain their high impact strength and ductility with normal aging. Tensile strength of Zamak 3 and Zamak 5 is somewhat reduced by aging (see table) but not to a degree which is significant in any usual application. Although all the zinc alloys undergo slight dimensional changes with aging, the changes are so small as to be of no significance in any but very exceptional applications. They are greatest in Zamak 2, but amount in this case to only 0.0007 inch per inch in four years of indoor aging and in the case of Zamak 3 and Zamak 5 to only 0.0001 inch per inch with the same aging, this latter being of the order of the thermal expansion of most metals.

All the zinc alloys are subject to some "creep" or "cold flow" when heavy, continuous mechanical stress is applied but the author can recall only one case in radio applications in which this has necessitated a change to another type of metal, this being an exceptional instance in which a very light part having an exceedingly long overhang and subjected to a continuous bending stress, as in a cantilever beam, sagged slightly. In virtually all cases involving the maker of radio equipment, any tendency toward creep may be disregarded.

Choice as among aluminum alloys is left, in general, with the die caster who is likely to be guided largely by his experience as to relative ease in casting, especially when the common form of "gooseneck" machine, in which air pressure directly on the molten metal is depended upon for injection, is the only type available. Some of the more recent "cold chamber" machines for die casting aluminum alloys are said to be equally effective on all types of aluminum alloys and to permit using some alloys not readily cast in "gooseneck" machines. Improved physical properties and denser castings in aluminum are said to be realized under the very high pressures applied in the cold chamber machine in which injection is accomplished by a positive ram. Data here given on physical properties of aluminum alloys are as listed in the appendix to A.S.T.M. specifications and are understood to apply to specimens die cast in gooseneck machines.

It is worthy of note that higher pressures are being used today in die casting all alloys than were common a few years ago. Most zinc alloy die castings are now produced at pressures ranging from 1200 to 2000 lb. per sq. in., as against 300 to 600 lb. per sq. in. a few

TABLE I—COMPOSITION AND PHYSICAL PROPERTIES OF ZINC ALLOY DIE CAST TEST BARS

	As Cast			After 4 Years Indoor Aging		
Manufacturers Designation	Zamak 2	Zamak 3	Zamak 5	Zamak 2	Zamak 3	Zamak 5
ASTM No.	21	23	25	21	23	25
SAE No.	921	903	925	921	903	925
Composition *ASTM and SAE:						
Aluminum per cent	3.5–4.5	3.5–4.3	3.5–4.3	......	......	......
Copper per cent	2.5–3.5	0.10 max.	0.75–1.25	......	......	......
Magnesium per cent	0.02–0.10	0.03–0.08	0.02–0.08	......	......	......
Iron, Max.	0.10	0.10	0.10	......	......	......
Lead, Max.	0.007	0.007	0.007	......	......	......
Cadmium, Max.	0.005	0.005	0.005	......	......	......
Tin, Max.	0.005	0.005	0.002	......	......	......
Zinc, Max.	Remainder	Remainder	Remainder	......	......	......
Impact Strength (Charpy) ¼x¼ in. test bar, ft.-lb.:	19	20	18	5	25	20
Tensile strength p.s.i.	47,900	40,300	45,400	49,200	34,900	38,200
Elongation, % in2 in.	5.1	4.7	3.0	4.1	8.2	5.1
Expansion with aging in. per in.	......	......	......	0.0007	0.0001	0.0001
Brinnell Hardness	83	74	79	......	......	......
Compressive strength p.s.i.	93,100	60,500	87,300	......	......	......
Electrical Conductivity Mhos/cm. cube at 20° C.	146,000	157,000	153,000	......	......	......
Shearing Strength p.s.i.	45,800	30,900	38,400	......	......	......
Specific Gravity	6.7	6.6	6.7	......	......	......
Weight lb./cu. in.	0.24	0.24	0.24	....	......	......

*Composition of Zamak alloys meet ASTM and SAE specifications but in some elements the limit are held closer than said specifications require.

TABLE II—COMPOSITION AND PHYSICAL PROPERTIES OF ALUMINUM ALLOY DIE CAST TEST BARS

Manufacturer's Designation	Alcoa 43	Alcoa 13	Alcoa 85		Alcoa 81
ASTM No.	IV	V	VII	VIII	XII
SAE No.	304	305	307	...	312
Nominal Composition %:					
Copper	...	...	4.0	1.5	8.0
Silicon	5.0	12.0	5.0	1.5	1.5
Nickel	...	....	....	2.25	...
Aluminum	Bal	Bal.	Bal.	Bal.	Bal.
Tensile strength p.s.i.	29,000	33,000	32,000	29,000	33,000
Elongation % in 2 in.	3.5	1.5	2.0	4.0	1.0
Impact strength (Charpy) ¼x¼ in. Test bar, ft./lb.:	4.5	2.0	2.5	4.5	1.5
Brinnell Hardness	60	80	70	60	70
Shearing Strength p.s.i.	18,000	22,000	22,000	18,000	26,000
Specific Gravity	2.70	2.66	2.78	2.72	2.85
Important or chief reasons for use	Ductility and Corrosion Risistance	High Tensile Strength. High Corrosion Resistance. Lowest Weight. Good For Large Castings	Good Casting Qualities. Fair Ductility And Corrosion Resistance.	Takes Anodic Oxidation Well. Useful For Small Simple Castings.	Low Cost General Purpose. High Tensile But Low Impact and Elongation.

years ago, but a great many excellent castings are still made at these lower pressures, including some of quite thin section. Results of research by the company with which the author is connected has not as yet revealed any benefit in improved physical properties from die casting the zinc alloys at pressures in excess of 2000 lb. per sq. in., but some die casters employ higher pressures with excellent results, especially in castings of quite thin sections. Small parts with sections as thin as 0.020 in. have been produced successfully and castings comparable in size to small radio cabinets are being produced with walls averaging little if any over 0.040 in., these being attained in at least one instance at pressures which are much lower than is usual today. It will thus be seen that it is practical to produce zinc alloy die castings which are nearly if not quite as light as corresponding stamped steel parts, while at the same time gaining the advantage of shapes with integral bosses, ribs and the like not usually feasible in stamped parts.

Neither the zinc nor the aluminum alloys are considered ideal as bearing materials, but either type is capable of carrying light bearing loads, such as are sometimes required in radio equipment, without undue wear, especially if some small amount of lubricant is present. Still better results are secured, of course, by the use of bushings, or of anti-friction bearings which in some instances are cast in place. In other instances, bushings or bearings are applied after casting, frequently in holes cored so close to size that only a light reaming cut is needed to yield the size required for inserting the bushing or bearing.

It should, perhaps be emphasized here that one of the major advantages of the die casting is the small amount of machine work needed, when any at all is required, to bring it to the size and smoothness necessary. Since it is produced in a die of steel having substantially fixed dimensions and, in general, having highly polished surfaces, and the temperatures both of the metal and of the die can be and usually are controlled within close limits, the casting itself is held within remarkably close limits and has, for a cast part, a surface of unusual smoothness. This not only results in an accuracy as to size which is often much superior to that of stampings, but in important economies in finishing where exposed parts are concerned. Die castings, such as automobile hardware and some radio trim parts that are to be plated, are produced in zinc alloy today with surfaces so smooth as they come from the die that no grinding and only a light buffing are required to prepare them for the chemical cleaning which precedes plating. This applies, of course, to major exposed surfaces and not to those at which a fin is formed at the die parting. Such fins are nearly always sheared or ground off by the die caster, but may require some further grinding by the purchaser if he does his own finishing.

Surfaces of die castings which require an organic finish can be made so smooth as they come from the die that only chemical cleaning to remove grease or foreign matter is required to make them ready for finishing, but in some cases scratch brushing or even a very light sandblasting may be used with advantage. This, of course, is in marked contrast to most sand castings on which much work in preparation for finishing is needed unless the finish itself is made quite rough to hide surface defects of the casting itself.

When machining of die castings is necessary, the cuts required are invariably light and involve the removal of very little metal. In general, they are confined to the simplest operations such as drilling, tapping, reaming or spot facing, which are done at a very rapid rate. Holes, often of irregular shape, are usually cored to size, but in some instances it may save in die cost to drill small holes or to punch even some of fairly large size holes, especially in thin-wall zinc alloy die castings. The coring of certain side or other holes may result in a fin which requires removal subsequent to casting, and in certain instances it is more economical to drill these holes or to punch them, if they are shallow, than to core them and remove fins. Tapped holes and external threads can be cast, but as chasing may be needed for required smoothness, it is often more economical to tap a hole or to cut an external thread than to slow the casting cycle by producing it in the die.

The foregoing outlines many of the considerations which dictate the use of die castings and control the selection of the alloys from which they are produced. As with many other types of products, however, it is profitable to examine specific examples of die castings to make their utility more evident than can be done by a mere recital of their properties and advantages. In so doing, it may be well to start with certain external parts and work inward, so to speak, toward parts which are hidden in normal service.

In so far as home receivers are concerned, the author has secured only one example (Fig. 1) of a case or cabinet which has been die cast and this is for a midget set. This case weighs only 28 oz. and measures 6¾ x 4½ x 4⅜ in. deep. It has an average section thickness of about 0.060 in. Those for whom it was produced are understood to regard it as superior to molded plastic cases in the contribution of the cabinet to the tone qualities of the set. Plastic cabinets are not so strong as those of the die cast type, especially if molded in corresponding section thickness, which probably would not be advocated. In addition, dimensional accuracy is likely to be better in the die cast cabinet. The die cast cabinet holds the possibilities of plated high lights and of other finishes which may be quite unusual as contrasted with the natural finish of the molded cabinet. Moreover, if a molded cabinet be dropped, it is likely to be cracked or broken beyond repair, whereas a cabinet, die cast in zinc alloy, is difficult to break in a fall and if dented or deformed can be straightened again, since die cast zinc alloy is quite malleable. As proof of the impact strength of die castings in zinc alloy, telephone bases have been dropped some forty feet onto concrete without fracture, though dented, of course, where they struck.

Fig. 2 shows another cabinet die cast in zinc alloy which while it is not a radio application and, in is the housing for an automobile heater, would serve as an excellent radio cabinet. It measures approximately 7 x 11 in. and is 4¼ in. deep, not including the horizontal bars forming the attractive grille across most of the front and one side. These bars are cast in one piece but not integral with the remainder of the housing, they have bright plated edges which contrast with the darker lustrous lacquer finish of the housing proper and on the upper and lower faces of the bars. The latter lend character and attractiveness to the assembly, forming with the main housing a unit which would prove outstanding as a radio cabinet. The walls of the housing have an average section thickness of approximately 0.042 in., making the case quite light. Holes for air passages are punched in the bottom and in one end, a procedure which presented advantages over coring as described above.

The high impact strength and ductility of zinc alloy die castings fit them well for automotive radio applications, especially since automotive manufacturers themselves are such large users of zinc alloy die castings

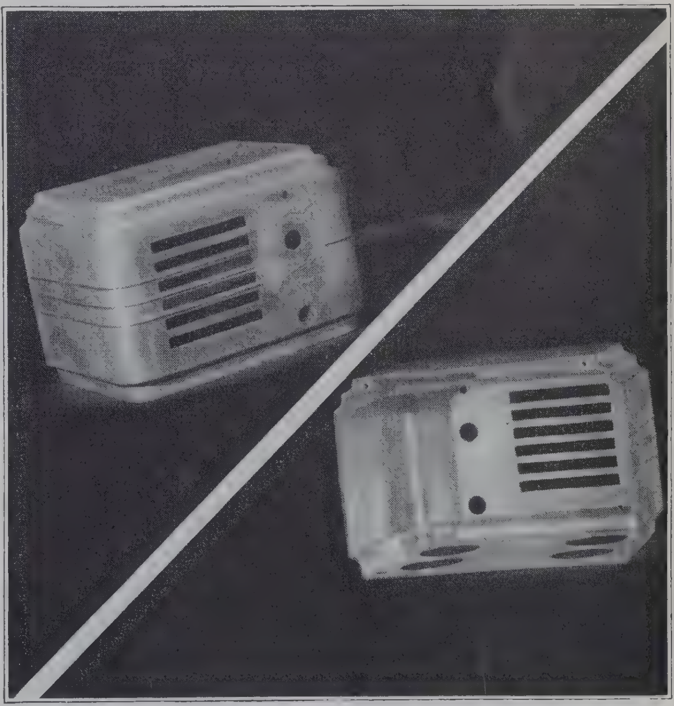

FIGURE 1. Cabinet for Silver Radio table receiver, die cast in zinc alloy with an average section thickness of only 0.060 in. which is much thinner than molded plastic cabinets, some of which are given a coat of organic finish similar to that required in this instance. The die cast case is produced more rapidly and with closer dimensions than molded cases and affords more interior room for a given set of over-all dimensions which in this instance are 6¾x4½x4⅜ in. deep.

and thus well know of their excellent performance where constant jarring and occasional blows may be received. Here the ease of securing a finish similar to that of other units included on the automotive instrument panel is a factor of importance, as is that of production in intricate shapes with uniform dimensions. For reasons such as these, a large proportion of automobile radio grilles and control housings are die cast in zinc alloy and are finished to match adjacent parts. At least one of the Philco radios for 1939 passenger cars has a die cast front housing with variety of openings and a section thickness at most points of only 0.043 in. This casting (Fig. 3) of course, has integral mounting lugs and other intricate details of shape which would be difficult if not completely impossible to produce in a stamped member of similar function. Such a stamping, incidentally, would weigh little, if any, less than the die casting and probably would lack the fine appearance of the die casting.

Complete housings for automobile radios have been die cast, but unexposed portions of automobile radio housings are commonly made from sheet metal which, under some circumstances is less expensive than the die casting, especially where a mere folding operation is the principal one required. It should be noted, however, that a sheet steel housing requires reinforcement or special attachment means at points of support and must be finished, at least to prevent rusting, whereas it is easy to provide integral mounting bosses on a die casting and since the metal is non-rusting no applied finish is required for hidden parts. Considerations of this kind constantly arise in the design of radio parts and ought not to be overlooked.

Many designers are so accustomed to working with sheet metal that they are prone to overlook the advantages of the die casting. In many instances, some of which are cited later, the die casting is not only better in various ways but also cheaper when die, assembly and finishing costs are considered. For this reason, it is well for the designer to study what can be done with the die casting and to avoid the unreasoned conclusion that any part formed from sheet metal will be less expensive. If there is any doubt in the matter, it may well pay to formulate designs of both types of part and to secure definite estimates both from die casters and stamping manufacturers. This is especially true in parts required in quantities of the order of 2000 to 100,000, for within this range the die casting is often the less expensive, when the die cost is considered in both instances. Production rates are usually higher with the stamping than with the die casting, often making the stamping the cheaper when the quantities are very large, but in other instances, the lower tooling costs for the die casting, the saving in assembly operations, the greater accuracy of parts, the non-rusting properties of the die casting alloys and the ease of producing complex as well as simple shapes make the die casting the cheaper and better buy.

Another factor is highly significant, especially when several small dissimilar parts are required for a given assembly. This is the fact that several such parts (See Fig. 4) can often be produced simultaneously in one die casting die having several cavities no two of which need be the same. Such combination dies often result in great economy favoring the die casting and are rarely feasible with the stamping. Thus, if it is necessary or advisable to die cast one part of an assembly, several other die cast parts are often made simultaneously at each shot of the die casting machine at only slight extra cost, whereas, with stampings, separate dies and separate set-up of each die is usually required.

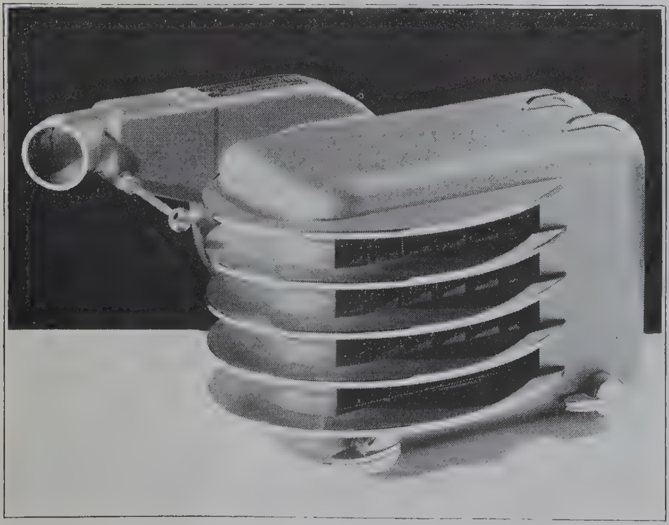

Fig. 2

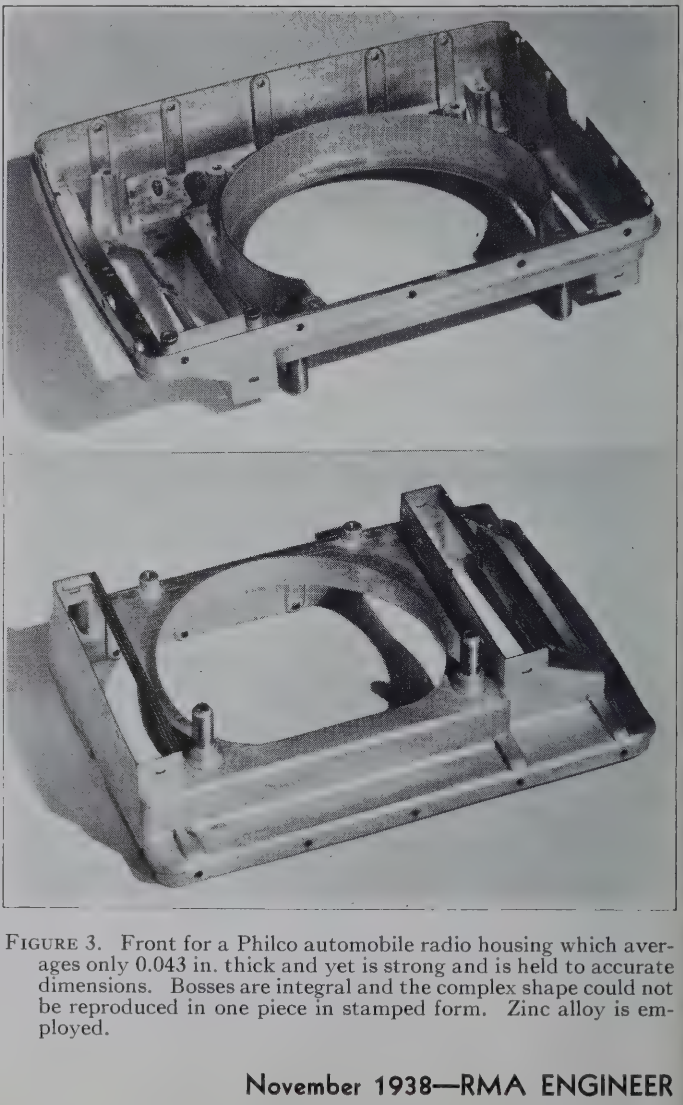

Figure 3. Front for a Philco automobile radio housing which averages only 0.043 in. thick and yet is strong and is held to accurate dimensions. Bosses are integral and the complex shape could not be reproduced in one piece in stamped form. Zinc alloy is employed.

Die cast cases or housings are not confined to radio receivers, of course, but can be applied with at least equal economy to other radio equipment such as the microphones shown in Figs. 4 and 5, for example. In such instances, the base and/or support of trunion may also be die cast, the base being made as heavy as desired to afford stability to the assembly. Accompanying illustrations and foregoing remarks should make the advantages evident without further comment on this score.

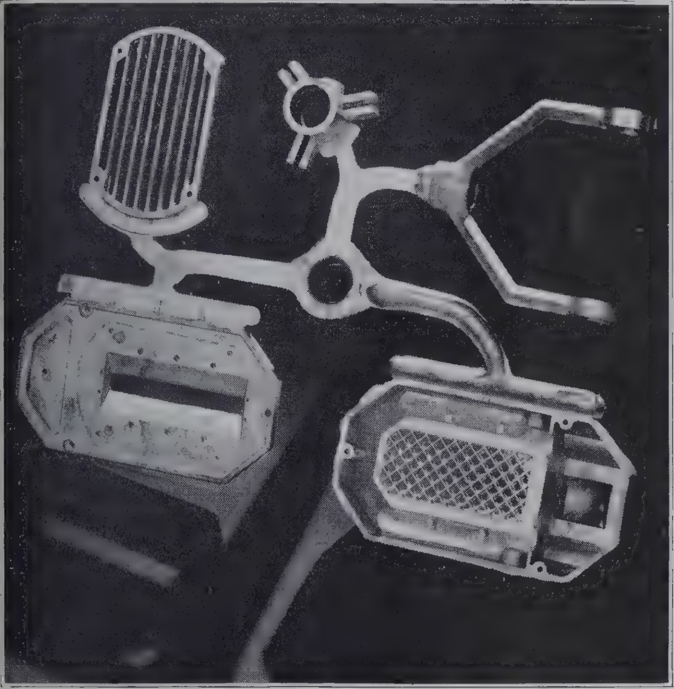

FIGURE 4. Gate of five separate die castings made in a single combination die in a single shot of the die casting machine, all the parts being for the same microphone. Such an arrangement makes for economy in construction which could not be duplicated in any other type of production on parts as complex as these.

Besides cabinets or housings, other exposed parts such as bezels, escutcheons, grilles, brackets, yokes, handles, louvres and the like are frequently die cast with economy and fine appearance, the latter often resulting from fine detail and sharp lines, sometimes with square corners all of which are not attainable by stamping processes unless resort is had to expensive coining operations. If, as is nearly always the case, the die casting is in zinc alloy, it can be readily plated or given almost any type of finish applicable to a stamped part. Combination finishes with plated and polished high lights and enameled recesses to afford contrast are readily attained. The technique of such finishing is well worked out and easily followed but differs in details from that for other metals than zinc. Details need not be given here*, but are available to all interested. The procedures, however, are as simple as in finishing other types of metal and are readily followed in any well equipped finishing plant. Some of the finishes yield mottled or wood-grain effect and others make possible types of highly attractive appearance not common in radio today. This suggests study of the possibility of die casting by those styling departments who are seeking new departures in appearance for future parts.

Several die castings in zinc alloy which are exposed in the finished product and contribute to its fine appearance will be found of interest and are here illustrated. They include a louvre, Fig. 6 which is employed in multiple arrangements on R.C.A.-Victor transmitters. These appear on painted doors and panels contrasting boldly with the brightly finished die cast louvres and with smartness not to be attained by louvres formed and finished integrally with the sheet metal doors and panels. Although transmitters are produced in relatively small quantities, a part, such as this louvre, many of which enter into the assembly of one transmitter cabinet, brings the total requirements to a point such that the cost of the comparatively small die required for production is fully justified. This is a point which neither the designer nor the "stylist," should overlook, for it enables him to gain at moderate cost, by the repetitive use of the same castings in a given assembly, an appearance hardly attainable otherwise with equal economy.

Such parts as knobs and handles and perhaps escutcheons or bezels, (Figure 7) may in certain instances be obtained in die cast form from specialists in die cast hardware as stock items and without any investment in dies. If a distinctive design is required, however, a special die is necessary, but this may still be quite within reason except where quantities are quite small. One maker of receivers points out that he is able to purchase die cast frames or bezels for use around dials to much closer limits than when molded plastics are used,

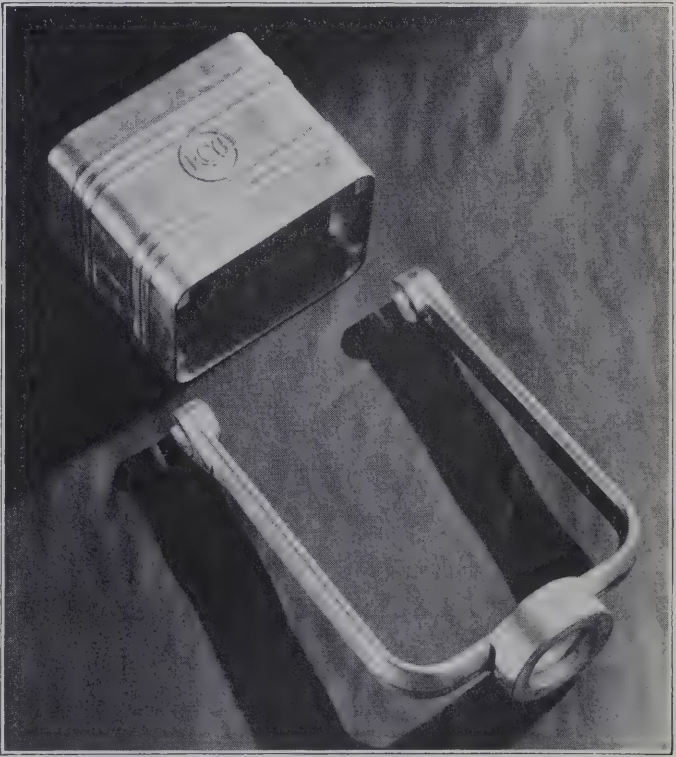

FIGURE 5. Trunion and part of the housing of an R.C.A.-Victor microphone die cast in zinc alloy. The bands and emblem form attractive high lights which can be polished with the background left dark if desired, making for attractive appearance.

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*See pamphlet entitled "Finishing of Zinc Alloy Die Castings and Rolled Zinc," available on request from The New Jersey Zinc Company.

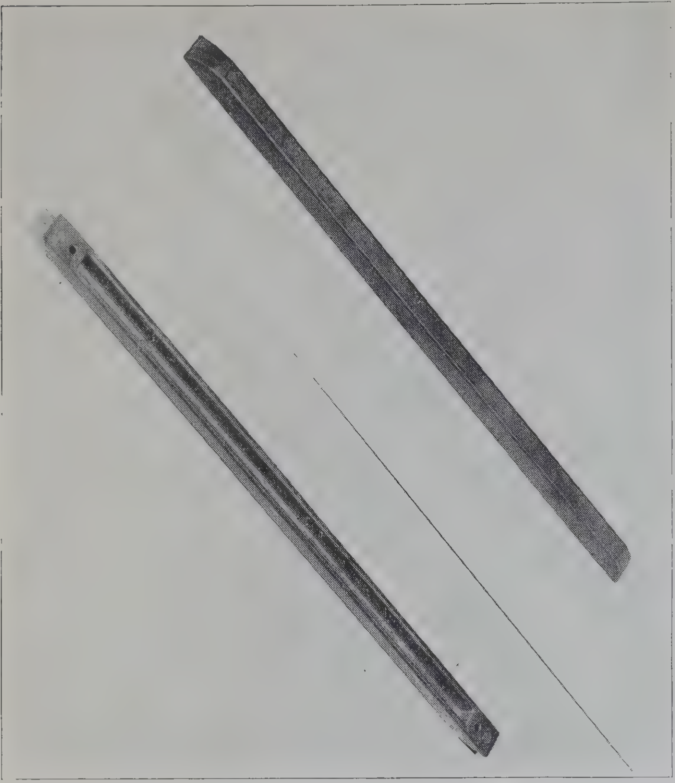

FIGURE 6. Combinations of several of these die cast louvre bars, attractively finished, are used effectively on painted steel panels of R.C.A.-Victor transmitters, producing a much finer appearance than would louvres pressed in the sheet steel panels themselves.

making a closer fit around push buttons and avoiding what he considers an unsightly gap between button and frame. In addition, the die cast frame may include, if desired, at least a portion of a housing back of it, avoiding the need for one or more other parts, and providing attaching lugs for mounting of push-button switches and the like or for gearing elements needed for remote control.

Several passenger car designers, profiting by their experience with smart looking radiator grilles, have chosen to die cast radio speaker grilles, to gain the same distinctive results as are indicated by Figure 8. Although some such parts can be stamped, they lack the distinctive qualities afforded by the die casting, sometimes yielding a "tinny" look and "feel" and the lack of rigidity completely absent in the die cast unit. At least one of last years automobile radio grilles was molded, but the stylist added some die cast parts for contrast. This year he is reported to have designed a grille which is substantially all die cast, the latter being much stronger than a molded assembly and presumably much closer in significant dimensions, although details have yet to be released.

Wurlitzer's latest automatic phonograph, which, of course, involves electronic elements in sound reproduction, is provided this year with a grille die cast in zinc alloy and has some corner decorative parts produced by the same means. All these parts are plated and polished; in line with efforts in this type of equipment to catch the eye of pay customers. This is the first exterior application of plated die castings the author can recall in a console type of cabinet except for bezels or rather small parts. In this instance, the bright plated die cast grille falls into a class which may not be well suited to cabinets for home receivers, but it does not follow that a die cast grille designed and finished in a manner suitable for home receivers might not be highly acceptable. There is, in fact, a good chance that a die cast grille designed to blend or pleasingly contrast with adjacent parts of a cabinet of almost any material might set a new style which would catch the public fancy. This too is a suggestion which seems to be deserving of study. It is not necessary, of course, to confine finishes to a white or bright metal type. Oxidized bronzes and other "antique" effects are readily produced as are many more modern finishes harmonizing with modern interiors.

One other die casting, a part of which is exposed on a home receiver, (See Figure 9) is deserving of special mention, as it performs some unusual functions. This is a frame or bezel around the dial openings of a recent Montgomery-Ward home receiver. Its small exposed parts are painted black. This casting is in zinc alloy and includes three transversely cored channels into which flat glasses slide. Of these, the center one is a ground glass for receiving the "movie dial" image. At each side are other glasses, one marked "Tone" and the other "Volume." Slots in the castings back of the glasses contain slides which are moved as volume and tone are varied. These two glasses are arranged for edge lighting, the edge exposed to the light being below a recess cored from the back and containing a lamp the socket for which is attached to a spring clip slipped over a prong provided on the casting. This casting also supports other portions of the assembly which is subsequently described. All these functions are combined in a single die casting which is much simpler to produce than would be any stamped assembly giving the same results and more accurate as to dimensions.

Applications already mentioned are sufficient to show that the die casting presents many advantages for use in exterior parts. Its utility in hidden structural and mechanical applications is at least equally important. Structural uses include a great variety of mounting or supporting brackets in which the die casting is ideal, for it can be made stiff, yet light in weight, and may have almost any arrangement of integral ribs, bosses, bearings, cored holes or recesses. It may have these disposed with faces

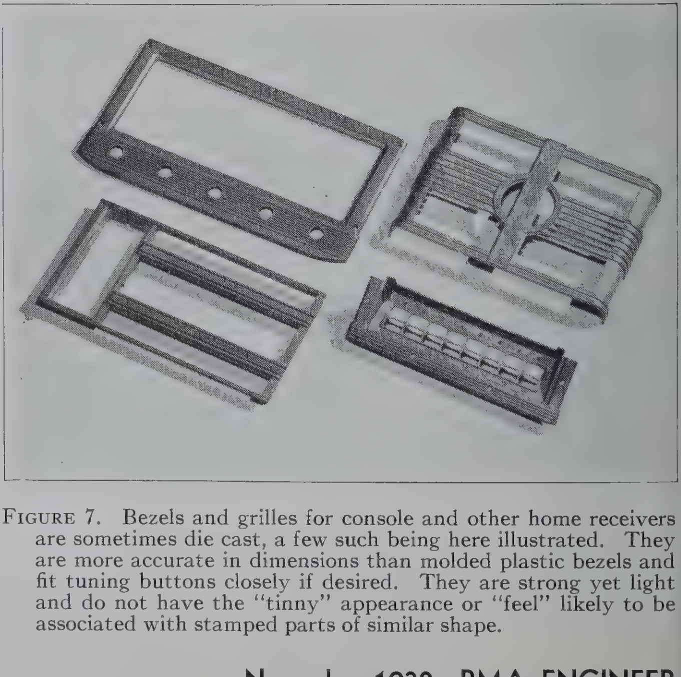

FIGURE 7. Bezels and grilles for console and other home receivers are sometimes die cast, a few such being here illustrated. They are more accurate in dimensions than molded plastic bezels and fit tuning buttons closely if desired. They are strong yet light and do not have the "tinny" appearance or "feel" likely to be associated with stamped parts of similar shape.

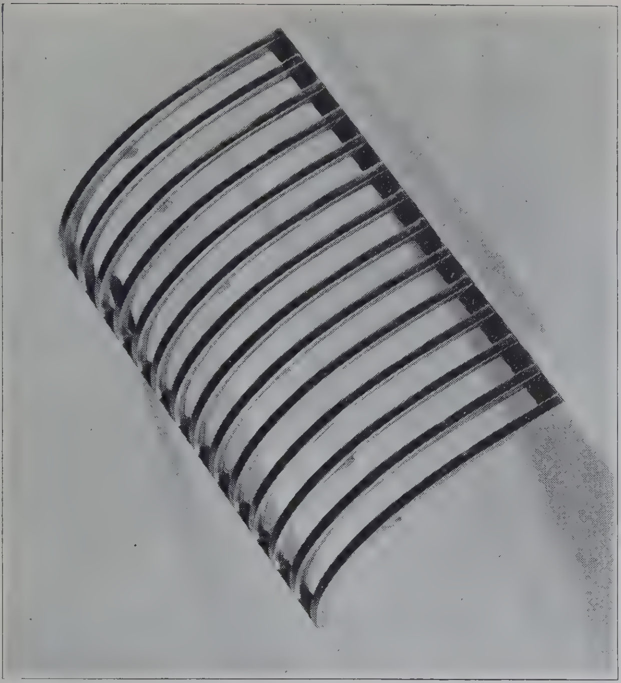

FIGURE 8. One of several die cast zinc alloy radio grilles (Buick) used to embellish instrument panels in 1939 cars. Such grilles are easily polished and plated. The one shown is designed with integrally cast lugs for attachment with speed nuts.

and axes in one or several planes and with assurance that sizes will remain substantially constant so that assembly with other parts is facilitated.

An excellent example of structural part is that forming a chassis or frame, Figure 10, on which numerous other parts of a motor-actuated tuning device are mounted. The casting carries the motor itself, has bosses with pivots for pulleys and reduction gearing and serves as a support for several other parts. Above the triangular opening a reversing switch is mounted and the casting includes four vertical projections each of which has a cored slot or channel in which tuning plungers are mounted. There are also bosses with holes serving as bearings for a cross shaft. To produce in quantities a part so complex as this in any other form than a die casting would involve a far greater expense than is involved in the die casting, for the latter comes from the die in one piece and practically ready for use except for possible light drilling, reaming, tapping or spot facing operations involving little time and expense and no significant waste of metal. The net result is a stiff, smooth and accurately sized part ideally suited for the function it performs. Although similar structural results could be secured with a sand casting, the cost for machining would be prohibitive and unmachined surfaces relatively rough. To produce the part with stampings would require a larger expense for dies and expensive assembly operations and would involve difficulties in maintaining the close dimensional limits readily maintained in the die casting.

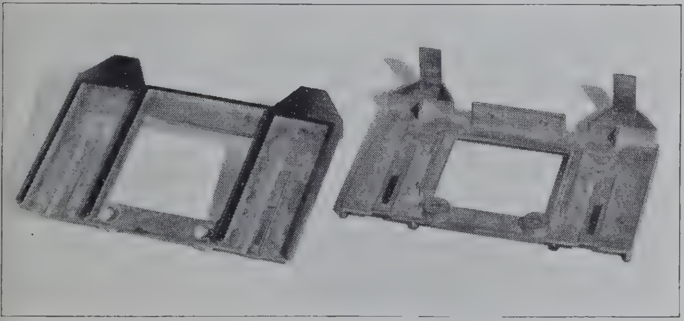

FIGURE 9. Front for Montgomery-Ward "movie dial" console radio, provided with cored channels for the ground glass and two edge-lighted side glasses for the tone and volume control dials. The latter are slotted and cover small sheet metal slides having projecting parts which pass through the slots and are attached to a spring at one end and to cords passing to regulator knobs on the other end. Recesses for the concealed lamps (with socket clamp slipped over the projecting clips) are seen at the top.

In another similar but less complex support bracket for a radio receiver shown in accompanying drawings, Figure 11, specific data on costs as between die castings and stampings are available. The parts compared are not duplicates in form, one being designed for die casting and the other for stamping as is desirable for proper comparison in costs. Both parts, however, perform identical functions and have the same dimensions where these are significant as to spacing of centers and mounting of parts. In the stamping, only blanking and very simple forming are needed, no drawing die, which often increases cost materially in stampings, being needed in this instance. Actual competitive estimates were secured by a radio manufacturer, that on the stamping, which is of cold rolled steel, including cadmium plating necessary to prevent rusting, whereas the die casting, being in zinc alloy, which, of course, is non-rusting, required no applied finish. The comparative figures secured are as follows:

	Stamping	Die Casting
Cost of die	$ 695.00	$ 410.00
Cost per thousand in lots of 5,000	107.40	139.50
Cost per thousand in lots of 20,000	107.40	138.00
Total cost, die included, lots of 5,000	1232.00	1107.50
Total cost, die included, lots of 20,000	2743.00	3170.00

It will be observed that, in lots of 5,000, the cost advantage lies with the die casting because of lower die cost, but the lower piece cost of the stamping resulting,

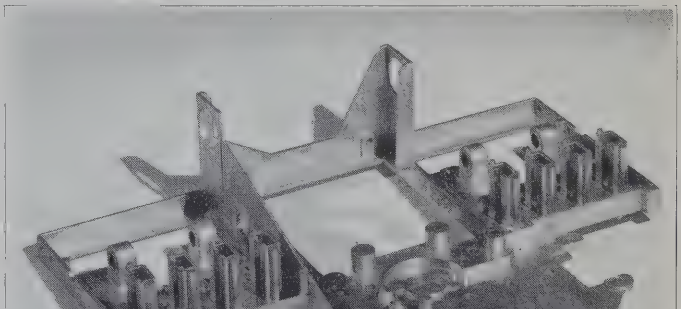

FIGURE 10. Chassis for motor-actuated tuning device, a one-piece die casting in zinc alloy with accurately cored holes for tuning plungers and for the mounting of numerous other parts. This is an excellent example of structural part which could not be produced accurately and in a form requiring so little machining except by die casting.

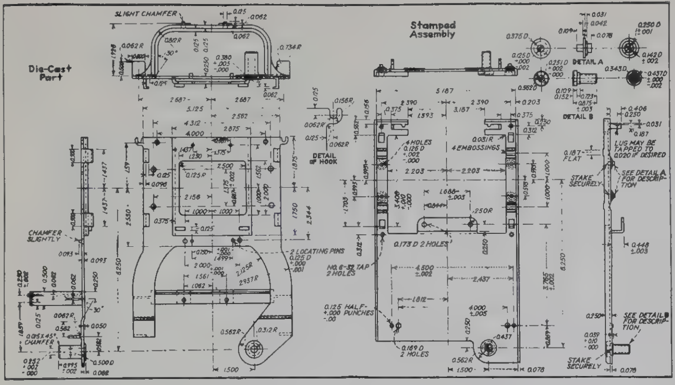

FIGURE 11. Drawings of die cast and stamped brackets designed for the same purpose, the die casting being produced in one piece with pivots, and the stamping requiring separately made pivots (made in the screw machine) and staked in place. Relative piece and die costs are given in the text.

presumably, from a somewhat lower cost of material and a higher production rate, makes the total cost lower for the stamping in lots of 20,000. In this instance, the die casting would have been chosen by the engineers concerned except for the fact that a longer time was required to make the die casting die and to secure delivery on finished die castings; a consideration which led to selection of the stamping. The latter, incidentally, required the addition by the maker of the stamping of certain parts produced on the screw-machine, these parts being supplied by the stamper and staked in place. Both types of part met structural and other requirements, but the die casting is certainly better in appearance and is the more workmanlike product. Had more assembly operations been needed, as is often the case when a stamped unit is complex, or had drawing operations been necessary on the stamping, it is probable that a still greater advantage for the die casting would have resulted, this doubtless including greater dimensional accuracy. There are, however, numerous instances in which die castings and stampings are combined to great advantage.

This is well illustrated by reference to the accompanying view of the combined movie dial, projector and variable tuning device, (Figure 12) employed in certain of the latest Montgomery-Ward receivers. In this unit, there are seven zinc alloy die castings, some with quite complex coring, many stamped parts, several screw machine parts and various other elements. The die castings include a pulley having two diameters around which pass cords, one operating the variable condenser and one a drum which carries a film in the form of a cylinder, the drum being another die casting. A shaft, forming the axis for the film drum, is mounted in inclined position by a well ribbed die cast bracket incorporating a boss on which is mounted a die cast lever for elevating the shaft and drum in shifting from one wave band to another. Attached to the drum bracket is a sheet steel support to which is attached, in turn, a die cast projector-lens housing, cored out to receive a lens barrel. Fastened to the lens housing is a die cast lamp housing and at the forward end of the sheet steel support and attached to it by screws is the die cast dial frame, referred to in an earlier paragraph, and shown in Figure 9 which holds the ground glass on which an image of part of the film is projected. Below and attached to the dial frame is a sheet steel assembly supporting the condenser with the die cast pulley referred to above and a shaft which carries the tuning knob. Space considerations preclude going into details concerning the die castings in this assembly, but it should be evident from the illustration that they could not be made by other means with adequate accuracy and at a cost comparable to that which the die castings make possible.

In mechanical parts such as pulleys, small gears, small flywheels, serrated parts, plungers, members with hubs and flanges and the like, such as are employed in automatic dial tuning, the adaptability or the economic advantage of die casting would seem too obvious to require extended comment. Several different makers of radio receivers have employed parts of this character, some of which are illustrated in Figure 13. The rather uncommon shapes which they assume, though well adapted to die casting, would be of prohibitive cost by any other form of production. As has already been pointed out, it is often feasible and highly economical to produce several such small parts, either duplicate or dissimilar, in a single die, and even making an entire set in a single cycle or "shot" of the die casting machine. The resulting parts are surprisingly accurate in dimensions, often requiring little or no machining, yet registering perfectly, as in the case of serrated plungers fitting similarly serrated holes, the plungers being cast with the serrations, of course, and the holes cored with mating serrations. Small gears, cams, squared, hexed or irregularly shaped portions are often formed in one piece which may include the shaft or a hole cored to receive it, thus avoiding the need for separate parts requiring numerous assembly operations. Such economies are characteristic of the die casting.

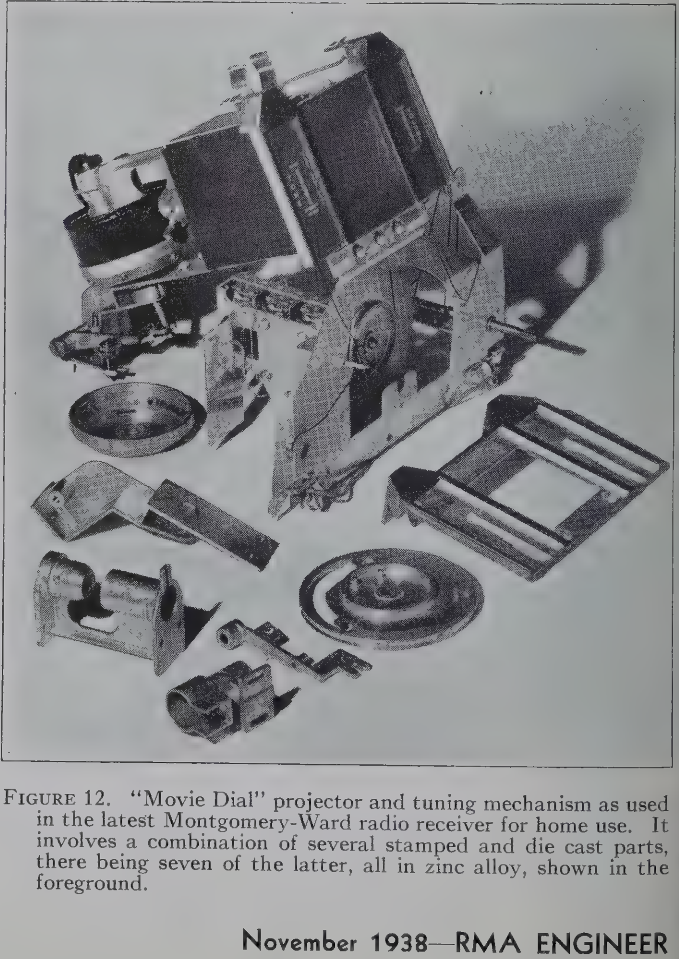

FIGURE 12. "Movie Dial" projector and tuning mechanism as used in the latest Montgomery-Ward radio receiver for home use. It involves a combination of several stamped and die cast parts, there being seven of the latter, all in zinc alloy, shown in the foreground.

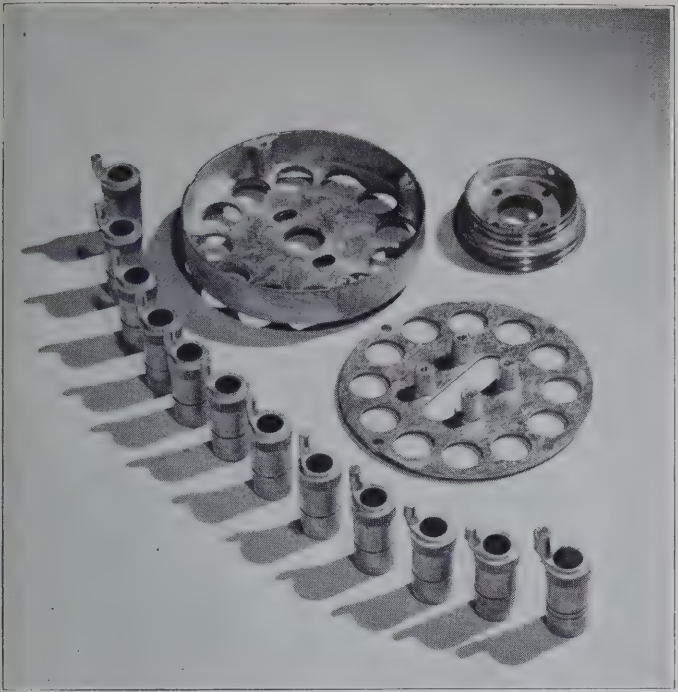

FIGURE 13. Some of the rather complex die cast mechanical parts employed in a Colonial dial tuning device, the plungers with external serrations fitting into mating holes in the largest of the die cast parts. The serrations, formed on the castings and requiring no machining, afford an economical means of making parts which would be much more expensive in any other form. Several radio manufacturers have employed similar assemblies of die castings for the same purpose.

Another specific die casting deserving mention is the thin-walled control housing shown in Figure 14. As will be seen, this includes a base having eight different compartments in which parts of the control are placed. The cover has mating partitions and bosses for connecting the two units and when in place divides the elements into fully shielded compartments. Similar housings could, of course, be made from stamped and drawn parts but would require several extra parts for partitions which necessarily would be separate and require assembly, rather than integral, as in the die casting. Fastening bosses would have to be applied separately also and the nicely rounded contours and fillets and neat appearance of the die cast housing would be lacking. Die cast housings of this general character might well find more extensive use by radio designers.

When the somewhat complex parts involved in phonographic apparatus, especially forms including automatic record changing equipment are concerned, it will be found that the die casting is virtually indispensable. The Wurlitzer automatic machine referred to above includes at least 84 die cast parts, nearly all, except the record holders, which are aluminum die castings, being in zinc alloy (See Figure 15). Parts for tone arms on phonographic equipment have long been die cast, as indicated by Figure 16, although some are produced in stamped form. R.C.A.-Victor employs a small two-part die cast zinc alloy housing, shown in Figure 17, for the crystal pick-up in certain of its tone arms and inside this a very small aluminum alloy die casting, here used for light weight, to hold the recording needle and the crystal itself. This aluminum die casting is supported in small rubber mountings which seat between the halves of the zinc alloy housing. The same phonographs are provided with an odd shaped needle cup die cast in zinc alloy and so arranged as to receive used needles and position the new one while it is being clamped in its holder.

Scores of other die castings used with success and economy in radio applications might be described but enough has probably been said, to make it apparent that radio engineers are rapidly becoming aware of the rather remarkable utility of such castings. It is recommended, however, that those not versed in the subject but concerned with matters of structural design study the accompanying illustrations with a view to gaining a knowledge of the utility of the die casting in the production of similar parts.

In a brief paper of this kind, it is not feasible to go very far into the subject of the general design of die castings, but a few general statements may be made. Those inclined to look further in the matter will find it dealt with in more detail in the book, "Die Castings" by Herbert Chase who has made an extensive study of the subject.

Almost any part of small to medium size which can be cast in sand can also be die cast, although cores which form an under cut such as to prevent their withdrawal are barred, of course. Often, however, ways of side-stepping this limitation are found, sometimes by making the part in two pieces. On the other hand, the die casting permits of small and remarkably accurate coring not feasible in sand casting and also of thinner sections and smoother surfaces than any unfinished sand casting can boast. Since the die is accurately sized and casting is done under a relatively uniform set of conditions, exceedingly close limits can be held and the variations between castings are usually insignificant, if reasonable care is exercised. Significant dimensions in zinc alloy die castings can often be held within 0.001 in. per inch of drawing dimensions, but a greater tolerance is desirable and there is no point, of course, in specifying closer dimensions than are necessary or than can be held in mating parts.

Designers not thoroughly acquainted with die castings and the limitations upon their design and produc-

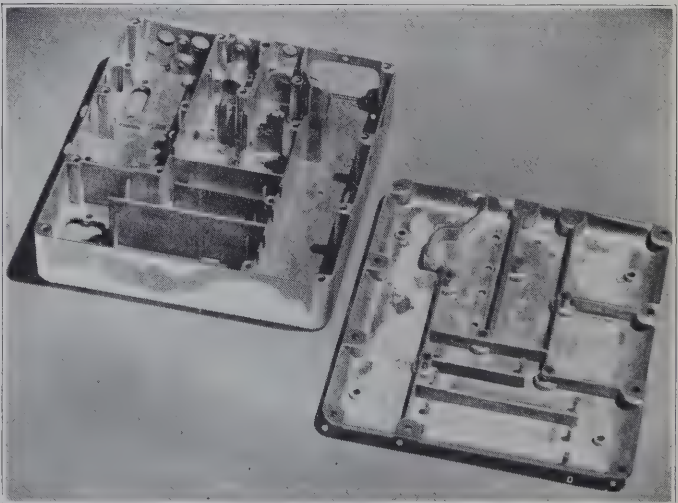

FIGURE 14. Two-piece thin-wall die castings in zinc alloy forming a neat and compact control housing for an automotive radio. Bosses and compartment walls are integral and accurate as to dimensions.

tion will do well to consult a competent die caster before laying down the design, as his advice is practically certain to result in economies not realized otherwise. It must be borne in mind that die castings are produced in rigid steel dies which, except for slides and side cores, are usually made in two solid halves. A parting comes at the joint between halves and leaves a parting line and a fin, which latter the caster nearly always removes. Of course, the casting must be made to clear the die and, if undercut, must have a slide or its equivalent to permit such removal. Cores with axes at right angles to the die parting usually add relatively little to die cost, but side cores, though often used, are likely to add considerably to die cost.

The cost of die castings can be minimized by reducing the thickness of sections to, but not below that required for strength and stiffness or to that which it is feasible to cast readily in the size of casting involved, whichever may be controlling. Many die castings including some here illustrated are made with greater section thickness than is necessary and thus cost more for metal than they need cost. It is futile, however, to specify sections too thin to be cast with reasonable ease and a minimum of rejects, hence the die caster should be questioned fully in this regard before a minimum section thickness is established. It may be said, however, that many die castings are now being made with sections over large areas of 0.040 in. or less. This includes many parts within the size common in radio work, hence, if a section of 0.040 in. is adequate for strength and stiffness, there should be apparent good reasons for greater thickness before they are selected. There are, to be sure, many considerations which may make it expedient or desirable to go to heavier sections, at least in parts

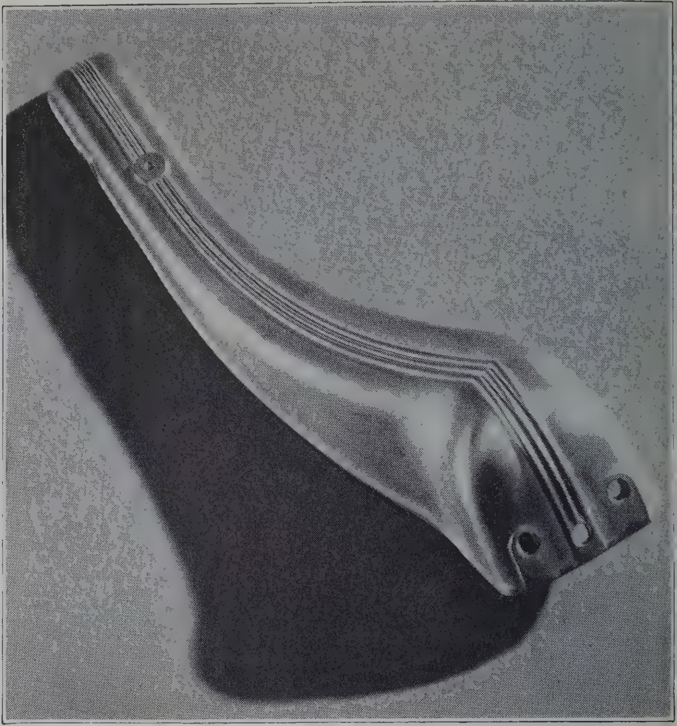

Figure 16. One of many neatly shaped tone arms for phonographs which have been manufactured as zinc alloy die castings, the process making possible an attractive appearance at low cost.

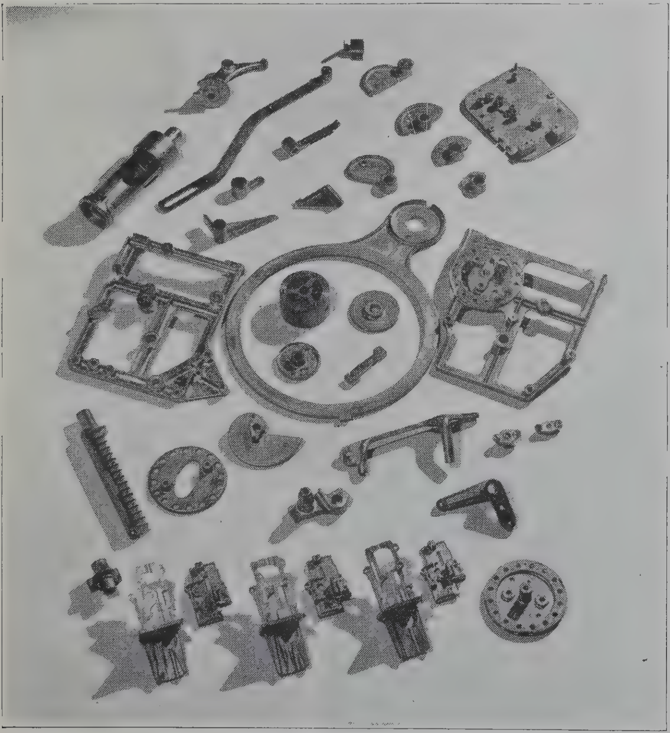

Figure 15. All these die castings are used in the Wurlitzer automatic phonograph and give an idea of the complex nature of many of the parts. All the die castings except the circular record frame in the center, which is in aluminum alloy, are produced in zinc alloy because of its low cost and excellent physical properties.

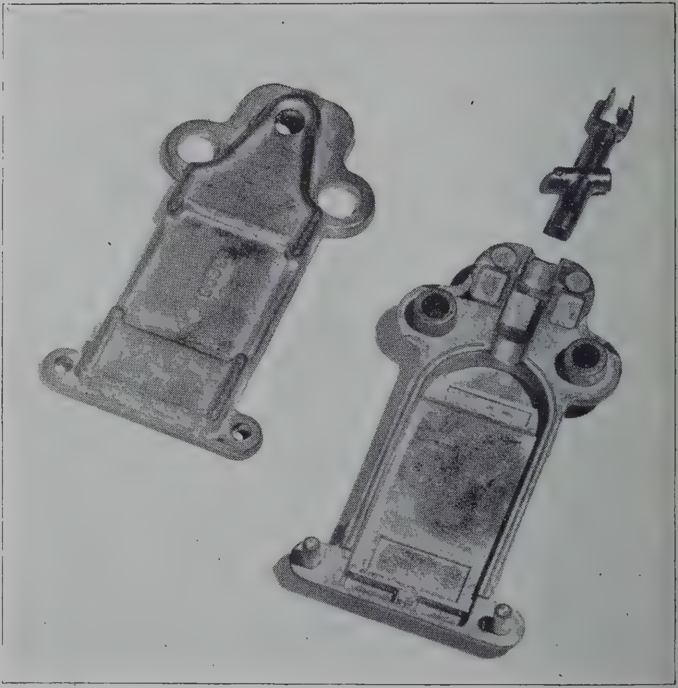

Figure 17. Pair of small zinc alloy die castings used to enclose the crystal pick-up mechanism used on R.C.A.-Victor machines. The two halves of the housing are fastened together by spinning or riveting over the projecting parts on one half after they are fitted through corresponding holes in the other half. The smallest part is an aluminum alloy die casting (for light weight) and is designed to hold the needle and, in its yoke, the crystal. This assembly is mounted in soft rubber bushings which fit bearing recesses formed in the halves of the case.

of many castings, but if the designer aims at the minimum section which can be cast and still give required results as to strength and stiffness, costs are quite likely to be minimized.

Large thin sections can be stiffened by ribbing and in some cases by the use of liberal fillets. The latter are desirable for much the same reason that they are in sand castings, but where sharp edges and corners are required, they can be cast. Drafts on cored holes and also on certain male portions of castings are usually required to facilitate removal of castings from the die. On cores, a minimum draft of 0.003 in. per inch of length and on side walls of about 0.005 in. per inch is usually sufficient for zinc alloys. Greater allowances are generally required for aluminum because it casts at much higher temperatures and has a larger shrinkage in cooling. In such matters, however, it is well to consult the die caster, as special considerations enter into individual cases. In general, it is cheaper to tap holes needing threads and to cut male threads than to form them on the casting, although there are exceptions to the rule. Teeth are readily formed in die casting spur, bevel and worm gears and with a degree of accuracy sufficient for many purposes, as are also splines, keyways, flats and the like.

Where greater hardness or strength superior to that of the die casting are essential, the use of steel or other inserts, either cast or pressed into place, may meet requirements and still save expense, although the cost of the insert and of applying it either in the die or to the part after casting naturally has to be given consideration. In some instances, however, inserts prove economical and solve a problem better than it can be solved otherwise.

When a die casting is to be attached to a stamping or to some other mating part, there are several alternatives to ordinary screws or rivets. Pins or tubular projections cast on the piece can be riveted or spun over after being inserted in mating holes or can be gripped by "speed nuts" which are rapidly and economically applied. It is entirely feasible also to bend or to form parts of a zinc alloy die casting or to punch holes for fastenings when this happens to be convenient or to economize in assembly.

Mention has been made already of finishes for die castings and it is not necessary to go into details here, as the subject is a broad one. A word of caution may be mentioned, however, especially as there are those who think of zinc surfaces as being hard to prepare for finishing if good adherence of the applied finish is to be secured. With modern methods, however, excellent adherence is readily attained and at very low cost. Either solvent or chemical cleaners are used to assure a clean surface. A simple phosphate treatment promotes good adherence of organic finishes. The procedure in plating is no more difficult or complex than with most other metals but requires care for best results. Details in this regard are available in a pamphlet already referred to and available to all who may be interested.

In conclusion, it may be noted that the die casting has made a secure and perhaps an enviable place for itself already in the radio manufacturing field. In other words, to use a popular phrase, it is "going to town" and those who care to "ride along" can certainly do so with profit if they make intelligent use of its possibilities. In common with other modern products, the die casting has its limitations as well as its advantages. In general, however, reasonable care and forethought in design enables the engineer to avoid unwise applications and to profit by those which are known to yield good results. The author and others in his company know both the limitations and the advantages, especially of the zinc alloy die castings and stand ready to share their experience with radio manufacturers who can profit by it.

THE RMA TELEVISION SYNCHRONIZING STANDARD—A SEMI-TECHNICAL EXPLANATION

(Continued from page 24)

The standard signal is practical. It has been in satisfactory use by various large television laboratories for several months. High-quality television pictures are being broadcast in New York City and Philadelphia using this standard.

8. Q. Will more than one type of receiving circuit successfully separate and handle the RMA signal?

A. Yes, at least three types of receiver synchronizing circuits can be employed in connection with the RMA Standard Television Signal. Probably no single receiver layout requires all of the requirements specified. However these are provided so several different types of receiver synchronizing circuits will operate from the standard transmitted signal.

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The RMA TELEVISION COMMITTEE reports to the Assistant Director of Engineering, Virgil M. Graham, who in turn reports to W. R. G. Baker, RMA Director of Engineering.

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CANADIAN INTERFERENCE METHODS

By R. A. Hackbusch, Director of Engineering, RMA of Canada

Since 1924 the Canadian Department of Marine, now the Department of Transport has been actively engaged in investigating, the causes of, and means of locating and suppressing, radio inductive interference.

A fleet of well equipped cars and a trained staff of technically qualified men operated by the Department has resulted in the collection of a great amount of important field data.

To supplement the field data the Department has conducted researches and has co-operated with the Electrical Industry and the R.M.A. in an effort to minimize the interference.

Realizing the need for greater authority to adequately cope with the situation, the Canadian Broadcasting Act included regulations governing interference, but no effective date was stipulated and no enabling legislation has been enacted. In order to make the Act effective, a conference of all interested groups was held in Ottawa during June 1938 and the co-operative steps necessary to put the Act into effect were "discussed".

The Federal Government in Canada has control over the use of electrical apparatus liable to cause radio interference, while the Provinces have jurisdiction over the matters pertaining to manufacture and installation. In view of the almost universal use of the Canadian Electrical Code throughout Canada, it was suggested that the Code could be enlarged to include regulations dealing with the nuisance value of interference, at the same time approvals tests for fire and life hazards were being investigated.

A tentative schedule of duties for the various groups was outlined so that data could be submitted to the Canadian Electrical Code Committee to be considered in specifications which will eventually be sponsored by the Canadian Engineering Standards Association.

The R.M.A. of Canada undertook to investigate methods and instruments for measuring interference, factors influencing interference on different grades of receivers and receiver susceptiveness.

It was agreed that certain rigorous aspects of interference standards must be set aside if we were to arrive at a commercial basis for considering the nuisance value of interference at an early date, to this end certain points which might introduce controversy were mutually agreed upon as the basis for suggested standards.

Due to differences in the results of measurements made with English and American tentatively standardized methods and instruments, a Canadian Standard is being proposed which will coordinate with both standards as it is realized that in the interest of International Trade, an International Standard is of utmost importance.

The Engineering Division of the R.M.A. of Canada, in order to obtain the maximum results in the shortest possible time, engaged the services of the Radio Research facilities at the University of Toronto to co-operate in making measurements and a final report on the results of this work will be published within the next few weeks.

RADIO MANUFACTURERS ASSOCIATION TELEVISION TRANSMISSION STANDARDS

T-101 **Television Channel Width**

The standard television channel shall not be less than 6 megacycles in width.

T-102 **Television and Sound Carrier Spacing**

It shall be standard to separate the sound and picture carriers by approximately 4.5 Mc. This standard shall go into effect just as soon as "single side band" operation at the transmitter is practicable. (The previous standard of approximately 3.25 Mc. shall be superseded.)

T-103 **Sound Carrier and Television Carrier Relation**

It shall be standard in a television channel to place the sound carrier at a higher frequency than the television carrier.

T-104 **Position of Sound Carrier**

It shall be standard to locate the sound carrier for a television channel 0.25 Mc. lower than the upper frequency limit of the channel.

T-105 **Polarity of Transmission**

It shall be standard for a decrease in initial light intensity to cause an increase in the radiated power (see Standard M9-121)

T-106 **Frame Frequency**

It shall be standard to use a frame frequency of 30 per second and a field frequency of 60 per second, interlaced.

T-107 **Number of Lines per Frame**

It shall be standard to use 441 lines per frame.

T-108 **Aspect Ratio**

The standard picture aspect ratio shall be 4:3.

T-109 **Percentage of Television Signal Devoted to Synchronization**

If the peak amplitude of the radio frequency television signal is taken as 100%, it shall be standard to use not less than 20% nor more than 25% of the total amplitude for synchronizing pulses.

T-110 **Method of Transmission**

It shall be standard in television transmission that black shall be represented by a definite carrier level independent of light and shade in the picture.

T-111 **Synchronizing**

The standard synchronizing signals shall be as shown on Drawing T-111. (Page 23 of this issue).

T-112 **Transmitter Modulation Capability**

If the peak amplitude of the radio frequency television signal is taken as 100%, it shall be standard for the signal amplitude to drop to 25% or less of peak amplitude for maximum white.

T-113 **Transmitter Output Rating**

It shall be standard, in order to correspond as nearly as possible to equivalent rating of sound transmitters, that the power of television picture transmitters be nominally rated at the output terminals in peak power divided by four.

T-114 **Relative Radiated Power for Picture and for Sound**

It shall be standard to have the radiated power for the picture approximately the same as for sound.

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Volume 3 November, 1938 Number 1

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LIMITING VALUES OF RADIO FILTER CAPACITORS AS USED ON PORTABLE APPLIANCES

The Joint Coordination Committee on Radio Reception of the Radio Manufacturers Association, the Edison Electric Institute, and the National Electrical Manufacturers Association has carefully studied the problems presented by the use of small capacitors for suppressing radio interference which may be generated at the brushes of commutator type motors, at the contacts of thermostats, and at the contacts of other types of electrical appliances.

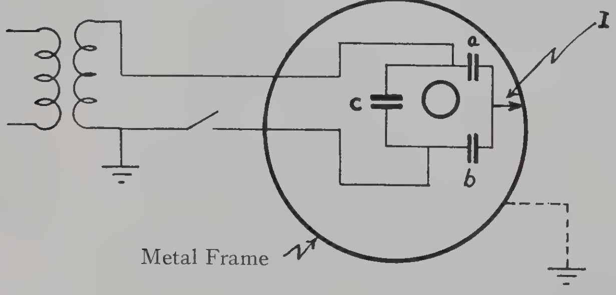
In metal frame devices these capacitors frequently are connected between the energized conductors of the device and the frame, thus giving rise to the possibility of objectionable shock. The choice of the suitable value of noise suppression capacitors is, therefore, a compromise between a desirably high value for purposes of noise suppression and a low value required for the avoidance of an appreciable possibility of sense of shock for the large majority of individuals under usual conditions.

As a result of the study of this problem, the Joint Committee has recommended, as tentative limits, that the maximum value of the capacitance to be connected between the windings and the case shall be such that the current to ground through this capacitance shall not exceed 0.3 milliampere with the switch or switches of the device in any position. Devices rated at 110 to 120 volts shall be assumed to operate 120 volts and at rated frequency. The accompanying diagrams illustrate the application of this limitation.

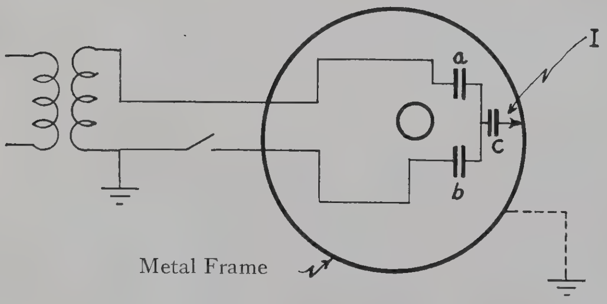
This study has not included consideration of devices where the frame is permanently grounded, as in oil burners, pump motors, etc., or where there is little likelihood of contact by an individual with the metal frame, as in the case of most radio sets. For such devices the limitation on size of capacitors for the avoidance of the possibility of shock does not, in general, apply. Nor has consideration been given to the make and break of switches which, as a rule, are operated infrequently.

It is recognized that the limiting value of current as here given may be subject to revision after further field experience.

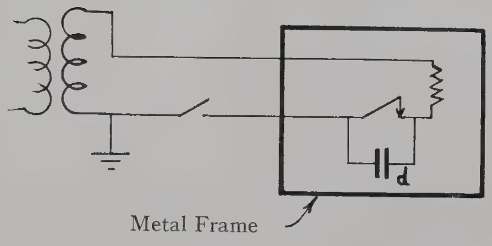
EXPLANATORY DIAGRAMS—(Not Connection Diagrams)



Capacitors "a" and "b" in parallel shall be of such size as to limit the current, I, to 0.3 milliamperes. The value of "c" is not limited.



Capacitors "a" and "b" not limited in size. Capacitor "c" limited in size so that the current, I, through "c" in series with "a" and "b" in parallel shall not exceed 0.3 milliamperes.



Capacitor "d" not limited in size by these requirements.

CHARACTERISTICS OF BROADCAST RECEIVERS

1938

By L. C. F. Horle, R. M. A. Data Bureau

This report presents in summary form data on the operating characteristics of the 123 different models of broadcast receivers produced by members of the Radio Manufacturers Association during the year of 1938 and reported to the RMA Data Bureau throughout the course of the year.

It will be remembered that late in 1937 there was organized within the Engineering Department and on a basis developed by appropriate subcommittees of the Committee on Broadcast Receivers a simple system for the centralized gathering of technical data on the characteristics of broadcast receivers going currently into the hands of the American public in the interest of ultimately having available within the RMA a detailed statistical knowledge of the characteristics of the equipment in use throughout the nation in the reception of all forms of broadcasting.

The system so developed includes the gathering of performance data and its submission to the RMA Data Bureau with respect to each model of broadcast receiver chassis built by the set manufacturing members in quantities in excess of one-thousand; the classification by the Data Bureau of the data so submitted, and its publication in such form as may be found of most general utility.

This, then, is the first report of the data gathered during the year 1938. It was, for the most part, submitted to the Data Bureau on Report Form No. 1-38A-2-1: there coded and transferred to special record cards which on completion of the year's accumulation were subjected to such statistical processes as have yielded the material given in this report.

In the several sections of this report are given summaries of the important receiver characteristics in one or more forms. Where correlation of receiver performance characteristics with some other distinguishing characteristics, such as number of tubes, number of variable capacitor sections, number of tuned circuits, etc., appeared of interest, such correlation has been attempted where justified by the submission of data on a sufficient number of models. In other cases only the distribution of the range of the characteristics of interest over the total number of models for which it was submitted and wholly without reference to classification of models is given. Wherever such a statistical distribution seemed justified by the number of available reports it has been determined and is given in addition to the attempted correlations.

In the summary of each group of data, reference is made to the number of the item on the report form under which it was submitted and to the pertinent section of the RMA instruction booklet on Receiver Test Procedure.

A classification of the models on which data was submitted on the basis of the type of power supply, the type of high-frequency amplifying circuit, and the number of tubes follows:

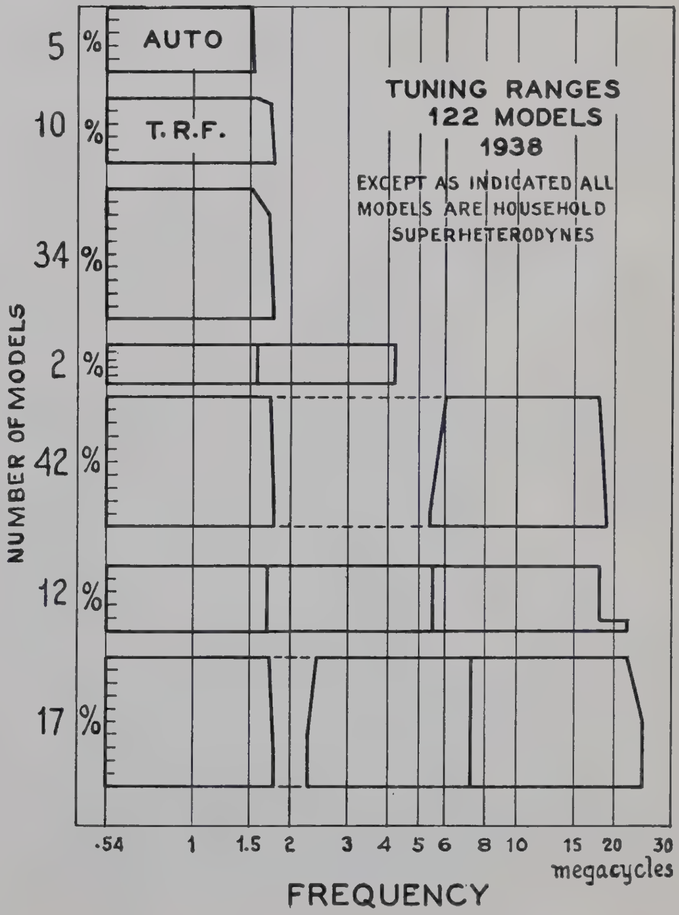
BATTERY OPERATED MODELS (Superheterodyne)				
Automobile, 5 to 7 tubes		5		
Other Storage Battery Models, 4 and 5 tubes		4		
Dry Battery Models, 4 to 6 tubes		11		
Total			20	
A.C. Operated Models				
T. R. F., 4 and 5 Tubes		10		
Superheterodyne		93		
5 Tube	20			
6 Tube	28			
7 Tube	14			
8 Tube	5			
9 Tube	6			
10 Tube	7			
11 to 13 Tube	13			
Total			103	
Total Models Reported				123

TABLE 1

Tuning Ranges

Item 11—Section I-(A)

In the presentation of the data on the tuning ranges of the models, the tuning ranges of the automobile models



and of the tuned radio-frequency models are shown individually. All other models have been grouped together and classified on the basis of the number and character of their tuning ranges, i.e., number of tuning ranges and whether these are of the discontinuous, 'skip band' type or, alternately, whether they cover the nominal range of the receiver continuously.

Sensitivity

Item 12—Section I-(B)

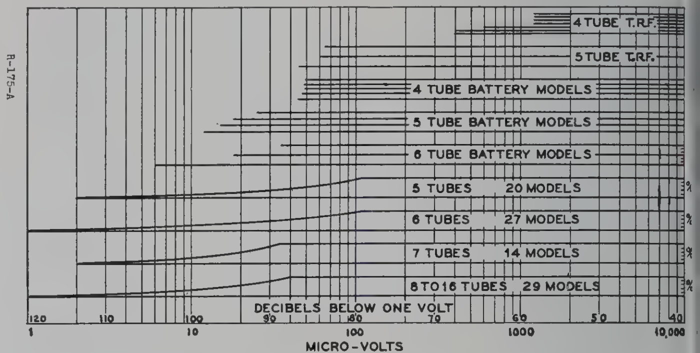
For the purpose of presentation of the data on sensitivity, the models for which this characteristic has been reported in such form as to be directly useable have been classified on the basis of the nature of the high-frequency amplifying circuits and on the basis of type of power supply and number of tubes.

It should be noted that while, for the most part, the data on sensitivity as submitted had been gathered in accordance with the detailed instructions on this score, in some cases the requirements of the instruction book with particular reference to the 'normal test output' have been departed from and the data so reported was, for the most part, neglected in preparation of this summary.

On the high-frequency ranges further classification on the basis of the number and character of tuning ranges is employed in the presentation of the sensitivity data. In each case only the sensitivity at the mid-band frequency is given.

For such added value as pictorial presentation may have, the data on the sensitivity of all models at 1 megacycle is given below in the figure so labelled In the cases of several classes of models of which the number was too small to here justify the averaging of the values of the sensitivity the individual values are shown by the horizontal lines. Where, however, a sufficient number of models of a class had been reported a block is shown, the upper boundary of which is the minimum sensitivity, the lower boundary of which is the maximum sensitivity, and the intermediate horizontal line is the average sensitivity of the models in that class.

In addition, there is given also the statistical distribution of the sensitivity of all superheterodyne models over the total number of these models without regard to any other distinguishing characteristic.



SENSITIVITY AT 1 M.C.
112 MODELS
1938

SENSITIVITY AT 1 M.C.—117 MODELS 1938

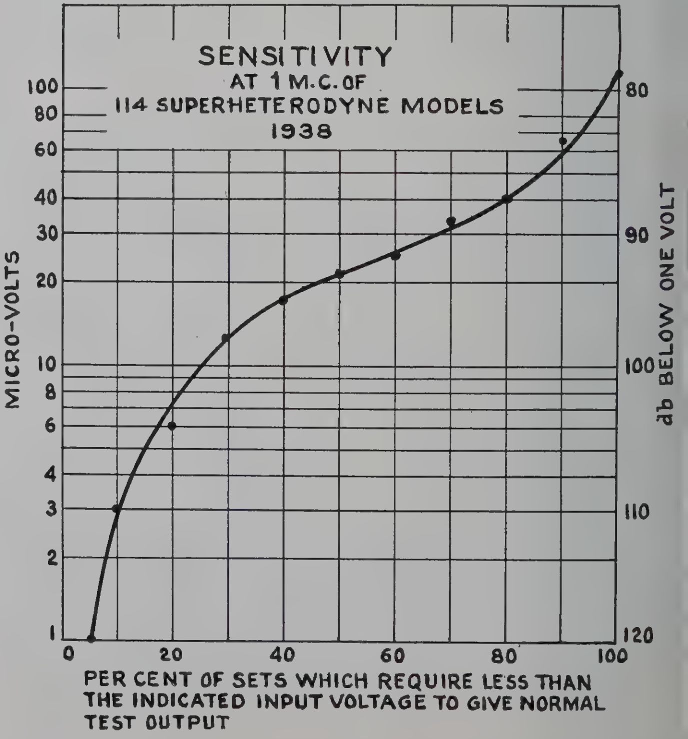
	Number of Models	Value of Sensitivity		
		Average	Max.	Min.
TRF MODELS				
4 Tubes	7	880 yv	1200	400
5 Tubes	3	56 "	63	45
Superheterodyne Models				
Automobile	5	3.3 "	10	1
Household	107	25 "	....	....
4 Tube, Battery	5	45 "	48	40
5 Tube, Battery	4	18 "	25	12
6 Tube, Battery	10	18 "	35	6
5 Tube, A.C.	20	43 "	115	2
6 Tube, A.C.	27	28 "	115	1
7 Tube, A.C.	12	22 "	35	2
8 Tube, A.C.	29	13 "	40	1

TABLE 2

HIGH FREQUENCY SENSITIVITY OF MULTI-BAND MODELS AT MID-BAND FREQUENCIES—1938

	No. of Models	Mid Band Frequency	Value of Sensitivity		
			Avg.	Max.	Min.
Dry Battery Models					
2 Bands, Continuous	8	10 mc.	53 uv	100	12
A. C. Models					
2 Bands, Continuous, 5 Tubes	2	2.5 mc	74 uv	..	..
2 Bands, Discontinuous, 5 to 13 tubes	32	10 mc	50 uv	150	12
3 Bands, Continuous, 6 to 15 tubes	12	3.2 mc 10 "	14 uv 24 "	38 45	2 3
3 Bands, Discontinuous, 6 to 14 tubes	17	4 " 12.7 "	35 " 53 "	87 110 87	1 1

TABLE 3



Selectance

Items 13 and 17—Sections I-(C), I-(D), I-(H)

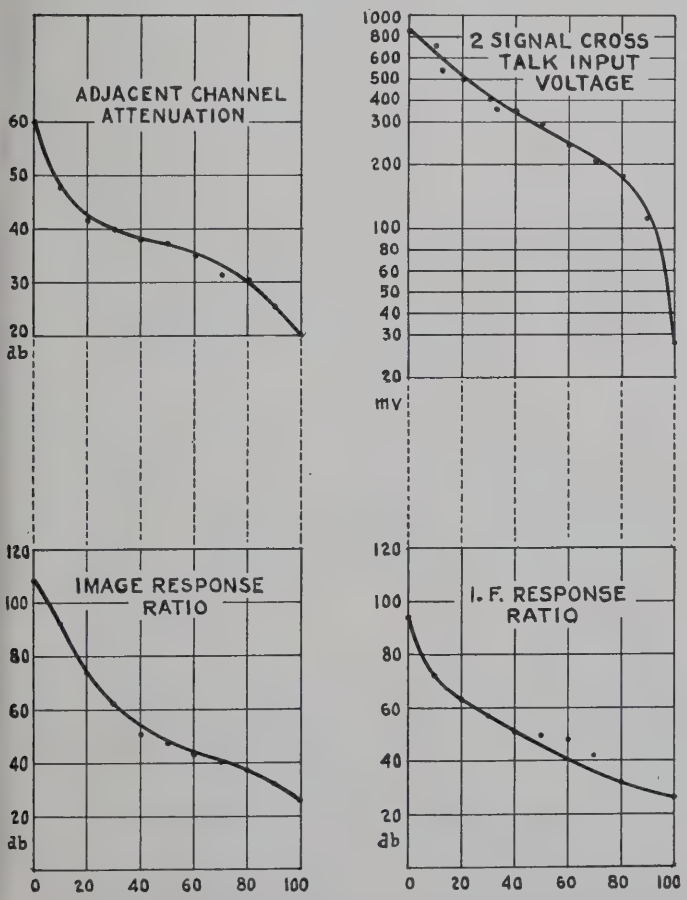
In presenting the data on the selectance, the data on the four selectance characteristics are here grouped together. These are, of course, the Adjacent Channel Attenuation; the Two Signal Cross Talk Input; the Image Suppression Ratio; and the Intermediate Frequency Suppression Ratio. Correlation between each of these four characteristics and the circuit details of the models has been attempted by the classification of the model on the basis of the number of tuned circuits and the presentation of the average, maximum and minimum values of the characteristic in each class. In addition, the average maximum and minimum values of the characteristics are given for all models without regard to any distinguishing characteristic.

SELECTANCE—1938

	Number of Models Models	Value of Selectance		
		Average Average	.... Max.	.... Min.
Adjacent Channel Attenuation...........	80	36 db	60	20
2 Variable Capacitors and 4 I.F. Circuits...	60	34 "	42	20
3 Variable Capacitors and 4 I.F. Circuits...	11	40 "	47	36
3 Variable Capacitors and 6 I.F. Circuits...	9	46 "	60	31
Two Signal Cross Talk Input................	55	347 mv	850	28
2 Variable Capacitors..	41	324 "	825	28
3 Variable Capacitors..	14	381 "	850	160
Image Suppression Ratio.	106	55 db	107	26
2 Variable Capacitors..	82	48 "	107	26
3 Variable Capacitors..	24	80 "	99	66
I. F. Suppression Ratio...	107	50 db	94	26
2 Variable Capacitors..	82	45 "	81	26
3 Variable Capacitors..	25	65 "	94	44

TABLE 4

SELECTANCE
1938



PER CENT OF MODELS HAVING SELECTANCES GREATER THAN VALUES INDICATED ON VERTICAL SCALES

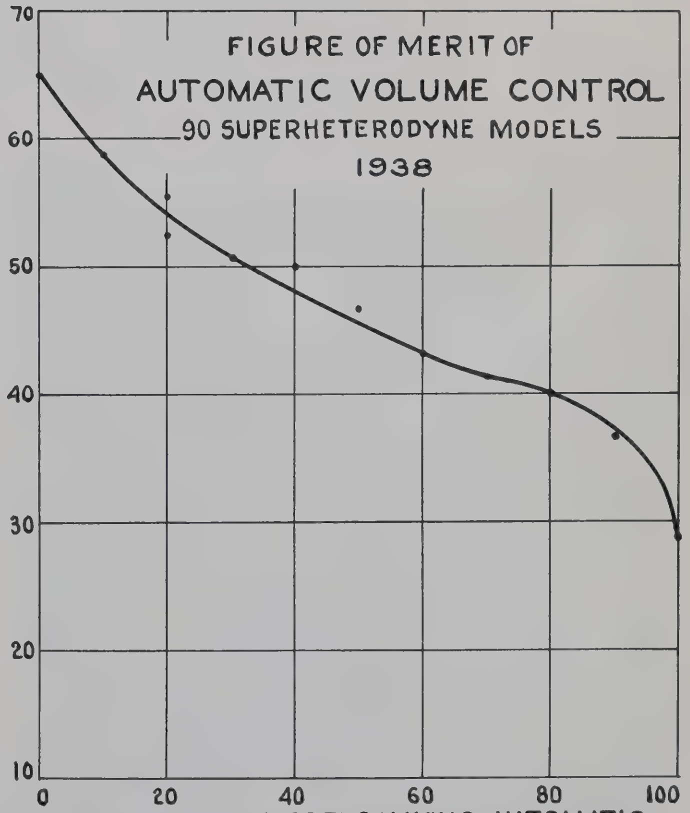
In addition to this classified distribution of the data on the several selectances, the statistical distribution of these several characteristics over the total number of models for which it was submitted, and without regard to any distinguishing characteristics of the models, is given in the graph below.

Automatic Volume Control

Item 16—Section I-(G)

In presenting the summary of the data submitted on the automatic volume control characteristics of the models, no attempt was made to correlate this characteristic with any other distinguishing characteristic of the 90 models for which it was given. The data is, therefore, given in a simple statistical distribution of the value of the characteristics over the total number of models for which it was given.

In reviewing this distribution it is, perhaps, well to keep in mind that what is here given is, in fact, the 'figure of merit of automatic volume control.' This is



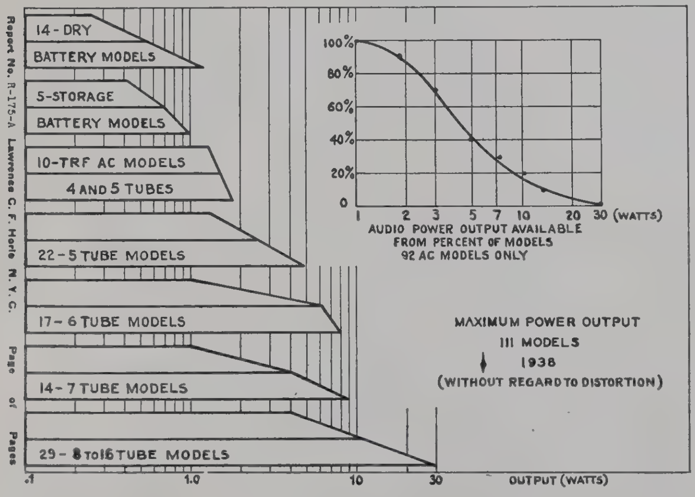
PER CENT OF MODELS HAVING AUTOMATIC VOLUME CONTROL GREATER THAN VALUE INDICATED ON VERTICAL SCALE defined as the reduction of input expressed in decibels, below an arbitrary value of input for which the maximum change in output is 10 db.

Accordingly, substantially all useable radio receivers may, by measurement, be assigned a value of this figure of merit whether or not they are equipped with specific A. V. C. circuits. Where the relation between input and output is linear the figure of merit assumes the value of 10 db. Thus, the effectiveness of the A. V. C. of the models reported on in the graph which follows may be assumed to be indicated by the amount by which the A. V. C. Figure of Merit exceeds 10 db.

Maximum Power Output
(Without Regard to Distortion)
Item 14—Section I-(E)

The data on the Maximum Power Output is given in the graph below. In this the data on the dry battery models, the storage battery models and on the T.R.F. models is given in separate blocks. All other blocks are indicative of the range of the maximum power output of A. C. Superheterodyne models classified on the basis of the number of tubes employed. In each block the upper boundary gives the minimum power output of each class, the lower boundary of the block gives the maximum power output, while the intermediate horizontal line gives the average value of the power output of the class.

In addition, there is given a statistical distribution of the power output over the total number of A. C. models for which it was submitted.



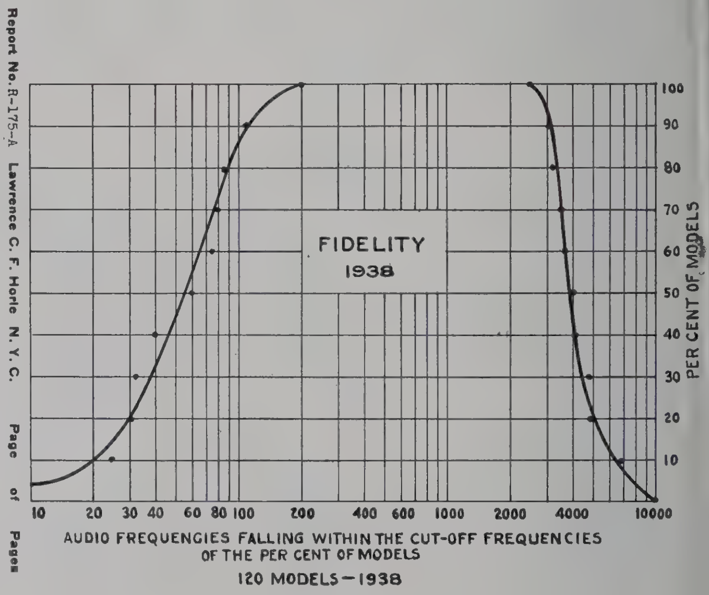
Electrical Fidelity
Item 15—Section I-(F)

In submission of the data on the electrical fidelity of the models only two numerical values were required by the data form. These are:

(a) The lower frequency at which the response is 10 db below the 400-cycle response and

(b) The upper frequency at which the response is 10 db below the 400-cycle response.

No correlation between these cut-off frequencies and other distinguishing characteristics of the models has been attempted. Instead, a statistical distribution of both the upper and lower cut-off frequencies over the total number of models is given in the graph below:



Type and Function of Tubes

A preliminary yet laborious attempt was made to establish correlations between performance characteristics of the models and the tube types employed in them. It was abandoned, however, in view of the fact that the large number of tube types and the relatively limited number of receiver models gave little promise of any generally useful correlations. However, the extent to which multiple function tubes were found to be employed in the models appeared to be of significance. With reference to this aspect of the data two tabulations have been prepared.

The first of these, as given below, indicates the extent to which specific electronic functions are combined in single tube structures.

Function	Per Cent of Models
Combined Detector and Oscillator	74%
Combined Detector and Amplifier (I-F or A-F)	3%
Combined Signal and AVC Detector	33%
Combined Signal and AVC Detector and Amplifier	64%

Of equal and, perhaps, of more general interest is the extent to which the number of electronic functions exceeds the number of tubes in the models reported on. This is indicated by the table which follows:

Excess Functions	Per Cent of Models
1	19%
2	28%
3	53%

(*Continued on Page 20*)

RADIO FREQUENCY GENERATOR FOR TELEVISION RECEIVER TESTING

By R. H. Turner, RCA Manufacturing Company

A radio frequency signal generator suitable for measuring the selectivity, sensitivity, and fidelity of television receivers must have performance characteristics radically different from those normally found in signal generators for testing conventional all-wave audio receivers. Briefly stated, a television signal generator should cover the most important of the assigned television frequency channels and should be capable of being modulated at frequencies throughout the desired video frequency spectrum.

The first requirement is made difficult of achievement because oscillator-amplifier performance becomes progressively worse at frequencies above 40 megacycles. Furthermore, leakage from the signal generator is apt to prove more bothersome than at lower frequencies. The seven assigned channels in the low frequency group for direct television broadcast are 6 megacycles wide and fall within the limits of 44 and 108 megacycles. The audio carriers have been tentatively placed 1/4 megacycles within the high frequency edge of each channel and the video carriers approximately 4.5 megacycles lower in frequency than the corresponding audio carriers.

The second special requirement, that is, wide band modulation, must be adhered to very closely, otherwise the quality of the transmitted picture will be unsatisfactory to experienced observers. The signal generator should be capable of transmitting pictures of a quality at least as good as those broadcast by the high power television transmitters.

It is customary to take selectivity curves of the video and audio channels of television receivers with the r-f carrier modulated at a fixed frequency of 400 cycles. On the other hand, for taking fidelity measurements of either channel a variable frequency sine wave source of modulation, perhaps of the beat frequency type, may be used. However, a sine wave test of the video channel will not entirely predict how this channel will respond to the irregular impulses encountered in the video signals. A good source of square-wave modulation for the r-f signal generator will give a more accurate test of the fidelity of the picture channel than will a source of sine wave modulation. Where faulty operation of the video channel of the receiver is to be analysed, the sine wave variable frequency modulation will be more useful in locating the trouble.

The television signal generator must fulfill the usual requirement that the output be variable over a minimum range of 100,000 microvolts to 10 microvolts. Another decade at each end may be useful occasionally, but this can usually not be obtained without providing exceptional shielding and without putting exceptional power into the output amplifier tubes. It is essential that the output attenuator be continuously variable, and that it preferably be logarithmic, and where selectivity curve-drawing equipment is to be used with the signal generator. The output impedance of the attenuator should, of course, be low compared with that of the receiver input circuit, but will probably be limited by the maximum voltage requirement and the available generator power.

In addition, the use of coupled curve-drawing equipment makes it desirable to have a linear variation of carrier frequency with respect to the movement of the frequency control to permit a uniform frequency scale on the curve of plotting paper. As part of the curve-drawing mechanism, it is very useful to have available at least three frequency scales, including one very slow one to permit the audio selectivity curves to be expanded to fill the paper. A third very wide frequency scale is useful when taking selectivity curves of the head-end or signal frequency circuits alone.

The required accuracy of the oscillator frequency dial depends upon how precisely the assigned frequency channels must be duplicated. For selectivity curves the absolute frequency is not as important as frequency differences. A consideration of all factors indicates that an absolute frequency tolerance of the oscillator dial of ±100 kc for the range of 40 to 100 megacycles is acceptable. This does not mean, however, that a total error from +100 to —100 kc should be permitted in as small a range as 4.5 mc, which is the present separation between carriers on the same television channel. A satisfactory oscillator dial should have divisions for each 100 kc and may have a vernier scale for dividing each division into ten parts.

Undesirable frequency modulation is not a serious problem in a television signal generator of the oscillator-

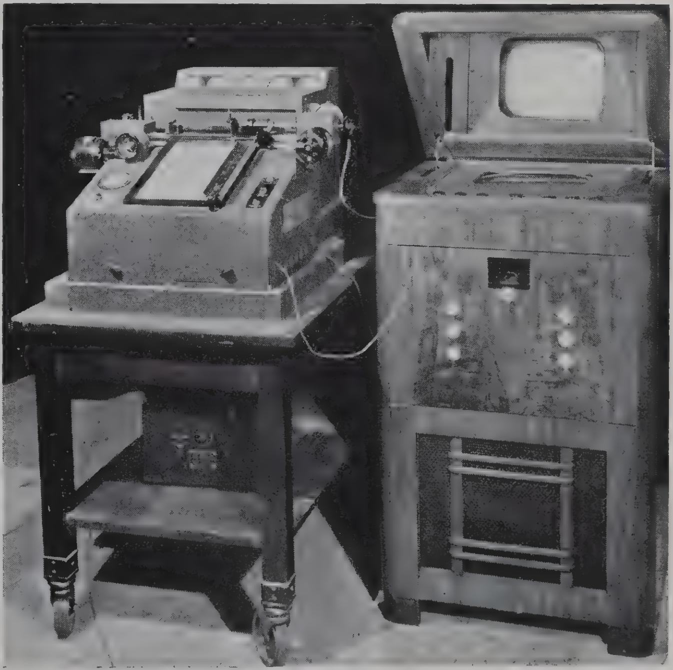


Fig. 1

amplifier type. The amount that may be tolerated depends upon the steepest slope of the selectivity curves of the sound or picture channels. The effect of frequency modulation is normally to increase the high frequency sideband and decrease the low frequency sideband, thus resulting in a frequency shift of the selective curve.

Quite closely related to frequency modulation is the frequency stability of the oscillator. The choice of the type of oscillator circuit and the circuit constants is very important if the oscillator is to have both high efficiency and good frequency stability.

The RCA Manufacturing Company, Inc., has had in use for several years automatic curve drawing television signal generator equipment fulfilling most, and more recently, all of the foregoing specifications. A photograph of one of the newer mobile equipments is shown in Figure 1. For all ordinary measurements this set-up can be utilized anywhere in the laboratory. But where interfering disturbances are present, both the signal generator and the receiver may be used in a suitably shielded booth.

After the operator connects this automatic signal generator and curve drawing equipment to the input and output of the television receiver as shown in Figure 1, and starts the motor driving the carrier frequency control, he need not touch any controls until after the equipment has traced the overall selectivity either of the video or of the audio channel of the receiver on standard semi-log paper. The frequency and signal input scales on the paper are direct reading, giving at a glance the bandwidth and sensitivity of the receiver.

This equipment operates on the principle of constant output voltage from, and variable input voltage to, the receiver. It therefore draws the conventional inverted selectivity curves, compressed, of course, by the logarithmic attenuator scale. The input voltage to the receiver is variable from 100,000 microvolts to one microvolt. The output voltage from the receiver may be set and held constant by the "servo-mechanism" at any level between 0.5 volt and 25 volts.

The curve-drawing unit at the front and the signal generator behind it are for convenience mounted on a common base but are electrically quite independent of one another and complete in themselves except as they are mechanically connected by two flexible couplings driving the carrier frequency and attenuator controls. Accordingly, other identical signal generator units without curve-drawing mechanisms may be used as small transmitters, each pair constituting one complete video-audio television channel, whose frequency may be readily changed to suit different conditions.

The signal generator unit itself is shown in Figure 2. The power supply for this unit is contained is a small separate unit. Essentially, the r-f portion of the signal generator consists of a push-pull oscillator of RCA-955 acorn triodes driving a push-pull modulated amplifier of RCA-954 acorn pentodes. R-F power from the wideband plate circuit of the amplifier tubes is transferred to the television receiver through an attenuator of the variable mutual inductance type.

The sources of variable frequency sinusoidal and square wave modulation are not included in this equipment but must be provided in addition. A 400-cycle sine wave modulator unit is, however, built into the signal generator for use in simple selectivity and sensitivity measurements.

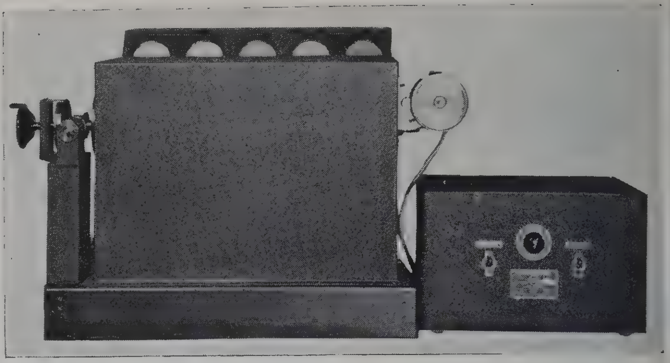


Fig. 2

Although the linear frequency control of both oscillator and wideband output circuits is obtained from a single shaft, the frequency relation between the oscillator and the output circuit may be shifted to suit different requirements. For example, as mentioned previously, it may be found desirable in the future to use higher frequencies in the high frequency video sideband, in which case the low frequency sideband must be attenuated to keep the transmissions within a 6-megacycle channel. Such prospective future requirements as this are easily met in this signal generator. Normally the output circuit drive-pulley is locked to the frequency operating shaft in such a position that the oscillator carrier remains approximately in the center of the output circuit response, transmitting equally both sets of sidebands out as far as 3 megacycles. But by shifting the output circuit drive-pulley slightly, the output response may be moved with respect to the carrier to favor and transmit one very much wider sideband at the expense of the other unwanted sideband. Since the displacement of the outer circuit is done at the shaft where rotation is proportional to frequency, the single sideband is favored very uniformly over the whole tuning range of the generator.

The five meters shown in Figure 2, indicate modulation in percent, oscillator plate current, amplifier grid current, amplifier plate current, and r-f voltage input to the attenuator.

Coupling amplitude correction has been introduced between the oscillator and the amplifier and between the components of the double output circuit so that the modulation percentage and the output voltage of the generator remain quite independent of carrier frequency. However, for unusually precise measurements, the operator may correct for slight variations of either.

In conclusion then, the special requirements of a television signal generator may be found in the electrical characteristics of the instrument just described.

Frequency Range (linear control)—40-100 megacycles.

R-F Output (continuously variable) 1-100,000 microvolts.

Modulation (from external source or 400 cycles internal) —30 to 3,000,000 cycles for both sidebands or may be altered for 30 to 5,000,000 cycles for single sideband.

R-F Output Impedance—50 ohms approximately.

Power Line Requirement—105-125 Volts, 60 cycles, 70 watts.

TELEVISION SYSTEM STANDARDS

Presentation to Federal Communications Commission

On February 9, a Special Committee of the RMA Engineering Department met with members of the Federal Communications Commission and its Technical Staff to discuss the recently approved Television Transmission Standards. Representing the RMA Engineering Department at this meeting were Messrs. D. E. Harnett, Chairman, J. E. Brown, A. F. Murray, E. W. Engstrom, I. J. Kaar, and P. J. Herbst.

As the material presented at this meeting quite thoroughly explains the reasons for the adoption of the various standards, it is reproduced here for the information of the members of the Radio Manufacturers Association.

The following material was presented by the members of the Committee, each giving a portion. Each standard is shown and is followed by the discussion:

Introductory Statement

This committee has been appointed by the RMA to deliver the television standards to you, to discuss them with you, and to explain the technical reasons for their adoption. We hope that we will be able to give you a clear picture of the television system defined by these standards, and to give you some idea of the reasons for their adoption.

The standards are the result of several years of work by the RMA television committee. The companies represented on this committee have been those RMA member companies who are actively interested in the problem. The membership has included some non-member companies who have been willing to advise on the standards. The system is not the product of any one company. The standards have been adopted after full consideration of all the possibilities and most of them have been tried in extensive field tests. As such they represent the best judgment of the RMA.

The record of the main committee's work is shown in the minutes. Copies of these minutes have been sent to you after each meeting. It has been the practice of the committee to continue the discussion until a nearly unanimous agreement is reached on any one standard. As a result, the minutes show that these standards were adopted with very few dissenting votes. In order that you may have a somewhat more complete picture of the reasons for the adoption of these standards than could be obtained from the minutes alone, we will present the reasons which were considered for the adoption of the several standards. In the course of the discussion the ideas of the several members were carefully considered and the mass of individual opinions was slowly fused into one opinion which is now that of the committee. This was done so completely that we are able to present you with not our own personal idea of the advantages of the features of the system, but a united opinion of the committee as a whole on nearly every technical point. In addition, as has been said before, that united opinion is very nearly a unanimous one.

One of the ways in which a television system differs from a sound broadcasting system is that the transmitter and receiver must fit together exactly. Not only must the receiver be able to follow the amplitude changes in the transmitter signal which correspond to the picture information but there must also be exact times and amplitude levels at which the signal envelope will transmit the synchronizing information and the black level information. These time intervals must be sufficient to allow the receiver to prepare for the next interval of picture information. This can be accomplished only by carefully specifying the type of signal which is to be transmitted.

The system is defined in 16 standards and in 2 items which are classified as recommended practice. The first 14 of these standards have been finally adopted by the RMA. They were transmitted to you last fall. Of the other 2, T-115 has been approved by the RMA television committee and the Board of Directors has authorized us to discuss it with you. The standard is being sent out for vote by all the member companies this week. The other standard, T-116, has been approved by the RMA membership. The two items of recommended practice have been approved in substance by the RMA committee handling them. We are including them in this discussion for the sake of completeness. We know of no one who opposes the adoption of these items of recommended practice, so we assume that in the course of time they will be formally approved.

The standards give sufficient information to specify completely a system. In other words, with these standards a transmitter manufacturer can construct a transmitter and another manufacturer may construct a receiver with assurance that the receiver will operate properly on the signal transmitted. If properly constructed, it will not be necessary for receiver adjustments to be made for a particular station.

The standards will be presented by the different members of the committee. We hope that you will ask any questions which occur to you as we go over them, so that you will understand the reasons for each standard.

T-101: Television Channel Width

The standard television channel shall not be less than 6 megacycles in width.

The frequency requirement of a television channel depends directly on the goodness of the picture to be transmitted. It has been determined that a 441-line picture has, in general, high entertainment value and provides good home television. In order to accommodate the frequency band required for this reproduction, at least a 6-megacycle channel is required. High definition television requires a channel width of at least 6 megacycles.

T-102: Television and Sound Carrier Spacing

It shall be standard to separate the sound and picture carriers by 4.5 Mc.

A single television channel includes both picture and sound signals. A definite spacing is necessary to permit single control receivers to be easily tuned to various programs broadcast from various television transmitters. Channels of 6-megacycle width were used as a basis for RMA standardization. All radiations are assumed to be confined to this channel width. The maximum utilization of this channel dictates vestigial sideband operation. Having determined upon the use of the vestigial sideband system, it is desirable that a maximum spacing between carriers be provided in order to permit the maximum modulating frequency to be used. Under these considerations it develops that a carrier spacing of 4.5 megacycles is available. This provides for a maximum modulating frequency of 4 megacycles which is satisfactory for high definition pictures. With one sideband suppressed, it is necessary to attenuate the surplus low frequency response, otherwise the undesired sideband would give excessive low frequency amplitude. How and why this is done will be explained in connection with standard T-115.

Using a 6-megacycle channel width and 441 line pictures the maximum modulating frequency, when double side band is used, is only about 2½ megacycles. Naturally, if one side band is partially suppressed the maximum modulating frequency possible within a 6-megacycle channel can be increased. It can be increased to 4 megacycles. Experience indicates that an increase in maximum modulating frequency, say 2½ megacycles to 4 megacycles, considerably improves the received picture to a degree that makes the use of a 4 megacycle modulation band well worth while.

T-103: Sound Carrier and Television Carrier Relation

It shall be standard in the television channel to place the sound carrier at a higher frequency than the television carrier.

Since we have a system in which two carriers will be used—one for the picture and one for the sound—and since each channel is to be complete, it is necessary to put the sound carrier either higher or lower than the television carrier and to agree on a uniform practice. There are no important factors for choosing either of the two possible carrier relations. Two minor factors are (1) that with the sound carrier higher in frequency and with normal superheterodyne operation, the sound intermediate frequency will be lower than the vision intermediate frequency. This is slightly preferable since the sound channel is the more selective and can be held to a closer absolute frequency when it is at a lower frequency. The second is that with the higher picture i-f the required band width is a lower percentage of the mean frequency. Both of these are convenience factors in receiver design.

T-104: Position of Sound Carrier

It shall be standard to locate the sound carrier for a television channel 0.25 Mc lower than the upper frequency limit of the channel.

The pass band of the i-f sound channel will be wider than that used in sound broadcast receivers because the receiver must be designed for simultaneous reception of two signals. Because of vestigial sideband operation for picture, the tuning must place the picture carrier accurately on the receiver selectivity characteristic. Thus a wide pass band in the i-f sound channel is used to permit a fine adjustment of picture tuning. A 0.25 megacycle spacing of sound carrier below the upper limit of the television channel is believed to be sufficient margin.

T-105: Polarity of Transmission

It shall be standard for a decrease in initial light intensity to cause an increase in the radiated power (See Standard M9-121.)

This standard of negative transmission permits more efficient use of the transmitter output for pictures which are predominantly white.

Also in negative transmission the synchronizing pulses represent the maximum transmitter output and it is therefore possible to work on the curved characteristic of the transmitter with pre-exaggerated pulses and reserve the linear portion for picture signals. The reverse is not true. In positive transmission white picture signals occur at maximum transmitter output. Consequently if an attempt is made to enter the curved region, there will result a loss of contrast between near-whites and whites, which means inferior fidelity.

There is a definite effect produced when using d.c. transmission which is entirely different for positive and negative transmissions. In positive transmission the transmitter output on peaks depends upon the amount of white in the picture. If there is no white the average output may be a small fraction of the peak output. The only steady component transmitted is the height of the synchronizing pulse which extends from zero antenna current up to approximately 25% of the peak antenna current which the transmitter can deliver. In negative transmission, on the other hand, the peak output of the transmitter is reached for each synchronizing pulse thus forming an excellent reference point for obtaining AVC.

The polarity of transmission enters into the question as to picture quality when noise is present in addition to the r.f. picture modulated signal. It should be observed that the natural limit of noise modulation is greater for inward modulation than for outward modulation. Thus in negative transmission noise will produce black spots on the picture which are less objectionable than white spots resulting from positive transmission. Noise in the case of positive transmission will cause interference with the picture whites; in negative transmission noise causes interference with the synchronization. Summarizing, it appears that the advantages and disadvantages of the two systems are about evenly divided except for the ease with which AVC can be added to the negative transmission system. The standard was therefore adopted based largely upon this latter consideration.

AVC is thought to be desirable because (1) of the reduction in natural fading effects, the effects of moving objects near the antenna, and the effects of moving antennas in windy weather, (2) the decreased range of manual control necessary and (3) the decreased differential in apparent picture level when tuning from one station to another.

T-106: Frame Frequency

It shall be standard to use a frame frequency of 30 per second and a field frequency of 60 per second.

In arriving at this standard, the following points were given consideration:

1. The desirability of having the system frequencies correlated to the power line frequency in order to minimize the effects of hum and to provide a readily accessible reference frequency. The predominant frequency in use by the United States power networks is 60 cycles. This suggests the use of this frequency as the basic rate for television transmissions. The use of 60 cycles will prevent

the pattern from residual hum originating in any part of the system from drifting across the picture and so becoming of greater importance since its motion relative to the picture arrests the attention of the eye. The choice of the 60 cycle repetitive rate limits such disturbance to a slight shading in the vertical direction which is hardly noticeable.

2. Elimination of flicker in the picture. The 60 cycle rate is substantially above the 48 cycle flicker rate, which is obtained with motion picture sound film at 24 frames per second, and although only half of the picture is transmitted in 1/60th of a second the two halves are interlaced so that the resultant effect on the eye is a flicker rate of 60 cycles and not, as might be supposed, a rate of 30 cycles. The persistence of the screens used for receiving tubes combined with the practical identity of the two picture halves has been proven experimentally to satisfactorily eliminate interline flicker, i.e. separate identification by the eye of the two sets of scanning lines comprising the picture. The absence of both frame and interline flicker is a most desirable result of the choice of the 60 cycle field rate.

3. Realization of the greatest amount of detail within a given frequency band necessitates transmission of the total picture information over the greatest length of time permissible under flicker requirements. This is the reason for interlacing. If the whole information is transmitted progressively and with the same number of lines in 1-60th of a second, the rate of scansion is doubled and the frequencies required to produce a given amount of detail will also be doubled. If the information is transmitted progressively in 1/30th of a second the frequencies will be the same as at present, but the flicker rate will drop to 30 cycles which is objectionable. Therefore the present standard of 60 interlaced fields per second, or 30 complete frames per second, provides a maximum of detail within a given band and with a suitably high flicker rate, minimizes the effects of hum and provides the transmitting station with a reference frequency. For these reasons, this vertical scanning rate has been adopted as standard by the RMA.

T-107: Number of Lines per Frame

It shall be standard to use 441 lines per frame.

In determining the number of lines per frame, the following considerations were kept in mind:

The necessity of obtaining an exact correlation between the frame and the line frequency requires that one be an exact multiple of the other.

The requirement which odd line interlacing adds is that this multiple be an odd integer.

The practical limits to which multiplication or division of frequencies can be carried is approximately 10:1. This necessitates that the multiple be the least common multiple of a combination of the odd integers, 3, 5, 7 and 9.

The frequency band available from Standards T-101 and T-102 is approximately 4 Mc. The horizontal and vertical detail should be approximately equal. Therefore the frequencies resulting from the scanning of horizontal detail equal to the maximum vertical detail, as determined by the line spacing, should be approximately 4 Mc.

The 441-line standard meets the above requirement. The factors of 441 are 3, 3, 7, 7. It is an odd integer. The maximum frequency required to produce horizontal detail equal to the vertical detail is approximately 4 Mc.

T-108: Aspect Ratio

The standard picture aspect ratio shall be 4:3.

The agreement with the film industry permits the transmission of motion pictures without the necessity of sacrificing some of the area of the original picture by clipping off a portion or of sacrificing any of the available detail by using less of the scanned area.

The importance of motion pictures in television program material makes it very desirable that the "Frame" which we provide fits the picture which we desire to transmit.

T-109: Percentage of Television Signal Devoted to Synchronization

If the peak amplitude of the radio frequency television signal is taken as 100%, it shall be standard to use not less than 20% nor more than 25% of the total amplitude for synchronizing pulses.

In a television system, it is necessary to devote some part of the modulation range transmitted to synchronizing. With the present system, wherein all synchronizing pulses are transmitted at the same amplitude, it becomes necessary to properly proportion the degree of amplitude devoted to synchronizing signals. The experience of several years of operation has indicated that 20% of the total amplitude is adequate. In proportioning the relative amplitudes of picture and synchronizing signal, if much less than 20% is devoted to synchronizing, then loss of synchronization will result in the presence of interference before picture quality is ruined, and, if much more than 25% is devoted to synchronizing, then, in the presence of noise, the picture quality may have been seriously impaired while synchronization still obtains.

T-110: Method of Transmission of Black Level

It shall be standard in television transmission that black shall be represented by a definite carrier level independent of light and shade in the picture.

Transmission of black level permits the synchronizing information to be kept on the same part of the characteristics of the tubes in the receiver, regardless of variations in picture brightness. Thus, the r-f and i-f portions of the receiver need, naturally, only about half the signal level required if the black level is not maintained.

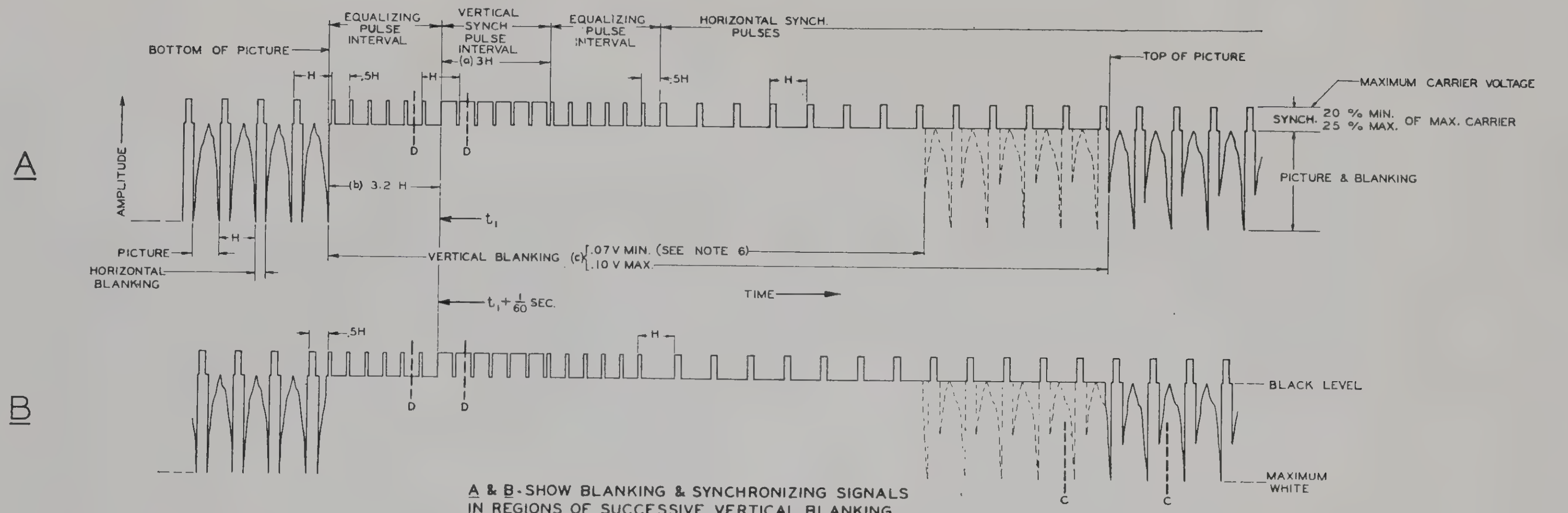
A definite carrier level permits the modulator at the transmitter to operate at the most desirable point on its characteristic. For instance, to handle the asymmetrical composite waves used in television it is desirable to fix the black level so that the synchronizing pulses always operate on the same part of the characteristic. This feature effectively doubles the modulation capability of the transmitter.

T-111: Synchronizing

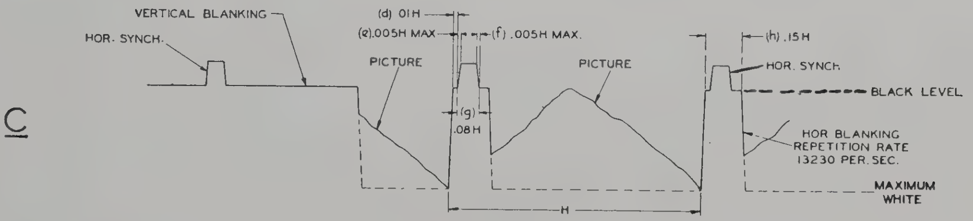
The standard synchronizing signals shall be as shown in the drawing on page 12.

Synchronization of the scanning at the receiver with that at the transmitter is accomplished by transmitting characteristic pulses at the end of each line and at the end of each field. In the transmitted television signal, these synchronizing pulses are represented by excursions of voltage in the direction representative of black in the picture and then they occupy a position corresponding to blacker than black. That is, while the picture signal occupies the portion of the total signal amplitude between a voltage representative of white and a voltage

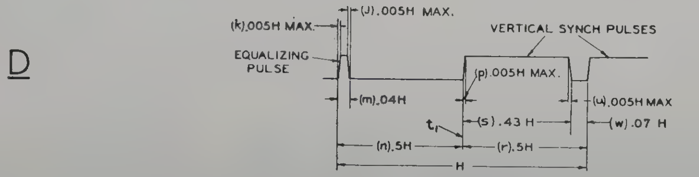
441 LINES, 30 FRAMES PER SEC., 60 FIELDS PER SEC., INTERLACED


A
B
EQUALIZING PULSE INTERVAL
VERTICAL SYNCH PULSE INTERVAL
(a) 3H
EQUALIZING PULSE INTERVAL
HORIZONTAL SYNCH. PULSES
BOTTOM OF PICTURE
TOP OF PICTURE
MAXIMUM CARRIER VOLTAGE
SYNCH. 20 % MIN. 25 % MAX. OF MAX. CARRIER
PICTURE & BLANKING
H
.5H
D
AMPLITUDE
(b) 3.2 H
t_1
PICTURE
HORIZONTAL BLANKING
VERTICAL BLANKING (c) .07 V MIN. (SEE NOTE 6) .10 V MAX.
TIME
$t_1 + \frac{1}{60}$ SEC.
BLACK LEVEL
MAXIMUM WHITE
C

A & B - SHOW BLANKING & SYNCHRONIZING SIGNALS IN REGIONS OF SUCCESSIVE VERTICAL BLANKING PULSES. (HORIZONTAL DIMENSIONS NOT TO SCALE. ALL DIMENSIONS ARE FROM BLACK LEVEL UNLESS OTHERWISE SPECIFICALLY INDICATED)



DETAIL BETWEEN C-C
DIMENSIONS TO SCALE



DETAIL BETWEEN D-D
DIMENSIONS TO SCALE

1- DIAGRAM C SHOWS ENLARGED DETAIL VIEW OF SIGNAL IN VIEW B BETWEEN LINES C-C

2- DIAGRAM D SHOWS ENLARGED DETAIL VIEW OF SYNCH. SIGNAL IN VIEW A BETWEEN LINES D-D

3- H=TIME FROM START OF ONE LINE TO START OF NEXT LINE = 1/13230 SEC.

4- V=TIME FROM START OF ONE FIELD TO START OF NEXT FIELD = 1/60 SEC. = $220\frac{1}{2}$ H

5- LEADING AND TRAILING EDGES OF BOTH HOR. AND VERT. BLANKING PULSES HAVE SLOPES (NOT INDICATED IN A & B) WHICH SHOULD BE KEPT AS STEEP AS POSSIBLE

6- RECEIVER VERTICAL RETRACE SHALL BE COMPLETE AT END OF .07 V representative of black, the synchronizing pulses occupy a region beginning at black level and extending from there in a direction opposite to that representative of white.

There is a blanking pulse at the end of each line for the purpose of establishing a black signal for systems having a return sweep. A similar black level blanking pulse is provided for each vertical synchronizing period.

These two types of synchronizing pulses, horizontal and vertical, are isolated at the receiver from the television signal and from each other and used to synchronize the operation of the reproducing mechanism with the scanning action at the transmitter.

The reasons for standardizing on the RMA television signal will now be reviewed.

(1) The synchronizing pulses are of greater amplitude than the highest picture signal so that selection of the synchronizing pulses from the television signal may be by amplitude difference. This is the only simple effective means of separation.

(2) All of the synchronizing pulses use the full signal amplitude assigned for synchronizing. This permits maximum effectiveness for synchronizing with a minimum of transmitter capacity.

(3) The television signal contains adequate information so that varied utilization circuits may be used and so that ample freedom is possible in circuit choice. Simple receiver circuits will assure proper interlacing. The field pulses are sufficiently long so that they produce an efficient isolated (isolated from horizontal pulses) vertical pulse by integration in either long or short time constant circuits. Isolated vertical pulses may be obtained by observing the fall of amplitude at the end of each vertical pulse. This freedom is possible because the rise and fall of each pulse is steep, each vertical pulse is less than one-half line in length; several vertical pulses are used; (as will be explained later) equalizing pulses (double frequency horizontals) of half-time duration are used during each field pulse period; and horizontal or line synchronizing is maintained during the vertical pulse intervals. For convenience, the rise of each vertical pulse serves as the beginning of each horizontal and each double frequency horizontal pulse.

(4) Equalizing pulses are provided at double horizontal frequency for a time of three lines preceding, during, and for three lines following each vertical pulse interval; these equalizing pulses and the horizontal pulses during this period are of half the time duration of the horizontal pulses during the major part of each field period. This assures that the isolated vertical pulses for even and odd fields will be identical and that no false vertical synchronizing positions will be produced (by reducing dissymmetry between and by preventing undesired low frequency components in the isolated vertical pulses.)

(5) The rise and fall of all pulse amplitudes are as steep as practicable. This results in numerous advantages:

(a) The final wave shape in the receiver is independent of the clipping level and reduces to a minimum the susceptibility of synchronizing performance to low-frequency interfering surges, such as, disturbances in receiver power supply.

(b) Effects of high-frequency interference on horizontal synchronizing accuracy is reduced because there is a minimum of time when such interference can disturb operation.

(c) Effects of high-frequency interference on vertical synchronizing accuracy is reduced because the rise and fall are steep and because the pulses remain at maximum for as long a time as possible. The method for utilizing the received signal influences the result, but in general, the signal-to-noise ratio will be proportional to either the energy transmitted or to the rate of change of energy.

(6) Horizontal blanking is 15% of one complete line period. This is a practical division for receiver design on the one hand and lost time on the other. Approximately one-half of this is allotted for the horizontal pulse to permit reliable operation of AVC and other circuits. Following the horizontal pulse, an adequate time at black level remains for operation of desired circuit functions.

(7) Vertical blanking is made just sufficiently long to permit vertical synchronizing operation and utilization of motion picture film projection as television program material. The blanking period is divided into four intervals.

(a) Equalizing pulse interval (preparatory);
(b) Vertical synchronizing pulse intervals;
(c) Equalizing pulse interval (following);
(d) Normal horizontal pulses.

Even and odd field period vertical pulses begin with one-half line difference in time position with respect to horizontal pulses to provide interlacing. Receiver vertical retrace shall be complete at the end of 7% of the field period, but transmitter blanking as long as 10% is permitted to accommodate use of motion picture material.

T-112: Transmitter Modulation Capability

If the peak amplitude of the radio frequency television signal is taken as 100%, it shall be standard for the signal amplitude to drop to 25% or less of peak amplitude for maximum white.

In general, it is desirable to provide for maximum modulation of a carrier. This is not always possible, for practical reasons, in a television transmitter. In order, however, to establish a minimum standard of excellence, the value of 25% was chosen as being a value achievable by practical television transmitters. Also this provides a definite figure to permit rational receiver design.

T-113: Transmitter Output Rating

It shall be standard, in order to correspond as nearly as possible to equivalent rating of sound transmitters, that the power of television picture transmitters be nominally rated at the output terminals in peak power divided by 4.

In view of the fact that, in television transmission, where d-c transmission is used, no average level of power exists and in order to conform to general transmitter ratings, it is considered to be good practice to divide the peak power by 4, as a working figure.

T-114: Relative Radiated Power for Picture and for Sound

It shall be standard to have the radiated power for the picture approximately the same as for sound.

When arriving at this standard, the following points were considered:

(1) The sound accompanying the picture should be as free from interference as possible. This points to radiating as high a sound carrier as is practicable. Experience indicates that approximately equal power for sound and picture results in practically equal service areas.

(2) It is uneconomical use of ether space and a source of unnecessary interference on other services if the service range of the sound transmitter is greatly in excess of the picture transmitter. This indicates the desirability of producing field strengths of equal magnitude from both transmitters.

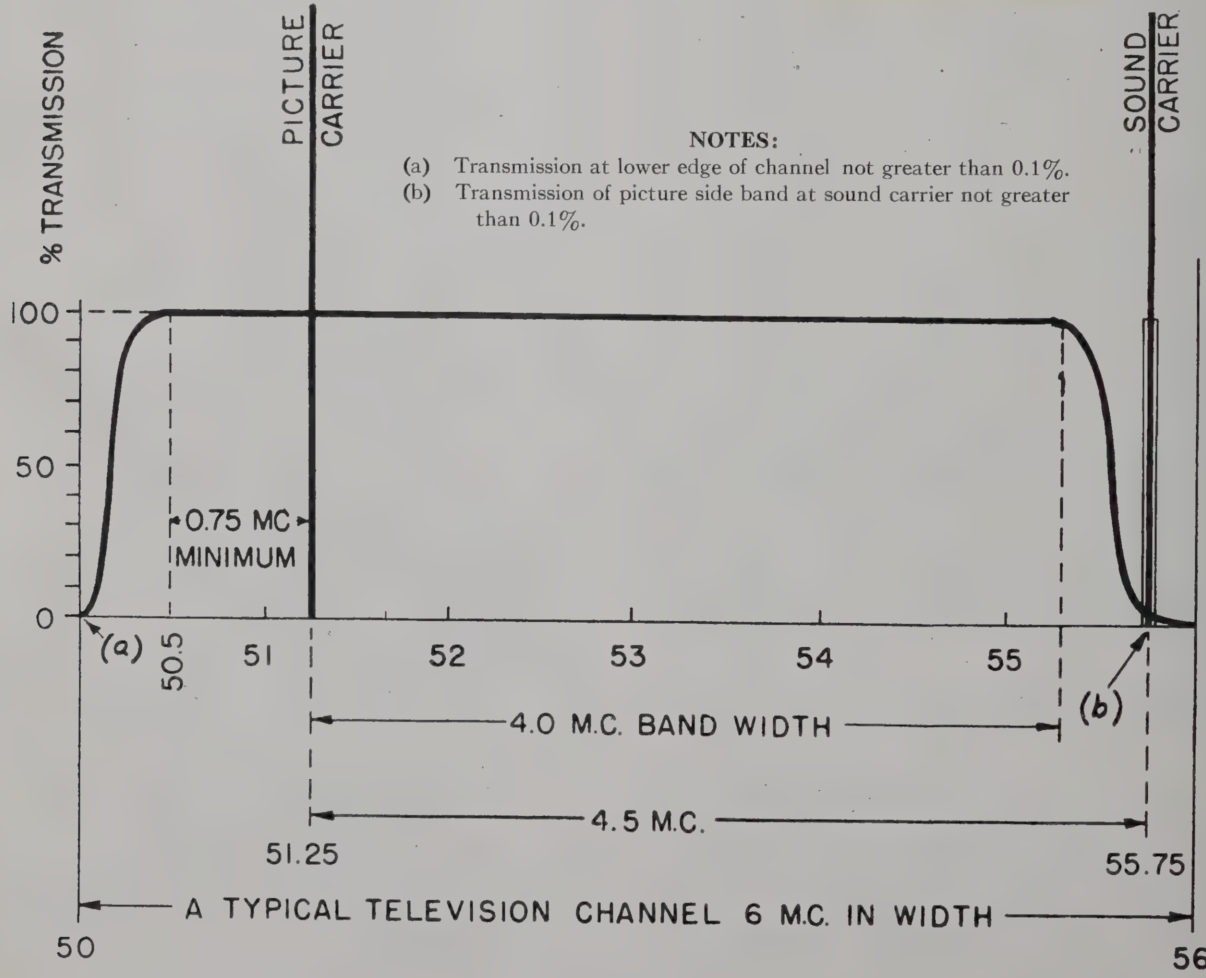
(3) In the interests of receiver simplicity and cost, it is desirable that the selectivity and the sensitivity requirements of the receiver be kept at a minimum. This again indicates equality of sound and picture power.

T-115: Transmitter Amplitude Characteristic

It shall be standard to use the transmitter amplitude characteristic shown on attached drawing entitled "Vestigial Sideband Transmission Amplitude Characteristic."

The separation between sound and vision carriers specified in standard T-102 makes it necessary to attenuate at least the outer portion of one sideband in the transmitter in order to avoid radiation outside the channel limits. Standard T-115 specifies the frequency limits within which this attenuation must be performed. The standard states that the transmitter shall have a flat amplitude characteristic including the upper sideband which is to be used for the picture transmission, the carrier and the lower .75 Mc of the lower sideband. In one method of receiver operation adapted for this transmitter characteristic the receiver is adjusted to attenuate the carrier by 6 db. The slope of the attenuation receiver curve is such that the correct portion of the inner sideband is attenuated to compensate for the vestigial portion of the outer sideband which is received. As a result the relative sideband and carrier frequency amplitudes at the video detector have the same relative magnitudes as they would if both sidebands had been transmitted and received. The rate of receiver attenuation is adjusted so that negligible signal is accepted at a point ¾ Mc from the carrier. With such an arrangement the receiver operation is the same as that obtained with double sideband transmitter operation and single sideband receiver operation. In the system chosen with the carrier attenuation taken at the receiver, the receiver passband width is less than in the other possible arrangements, such as double sideband operation, or other methods. Since the cost of the receiver increases with increase in the required pass band, this tends to make a more economical receiver. This particular factor is one which the committee considered to be of major importance. In setting up a television service it is advisable to add considerable expense and complication to the transmitter in order to achieve even a small reduction in the cost of the receiver. Certainly, we do not want to adopt standards which will require a more expensive receiver than is necessary to provide good service.

(*Continued in Next Issue*)



NOTES:
(a) Transmission at lower edge of channel not greater than 0.1%.
(b) Transmission of picture side band at sound carrier not greater than 0.1%.

SURVEY OF CROSS MODULATION AT SEATTLE

By L. C. F. Horle, Consulting Engineer

This report supplements that given in RMA Bulletin No. 28 on the "Survey of Cross Modulation" at Seattle, Washington. It summarizes the material of that report and on the basis of measurements made at Seattle since the preparation of Bulletin No. 28, points out some of the quantitative relations involved in the generation of spurious signals of the "Cross Modulation" type, due to non-linearities in the transmission path.

It will be remembered that the extended cooperative study of cross modulation by the Engineering Department of R.M.A. at Seattle, and elsewhere, was authorized by the R.M.A. Board in order that an unequivocal report might be made of the causes of the spurious signals so generally reported from the Seattle area, and that preliminary investigation indicated that, for the most part, the spurious signals resulted from cross modulations arising not only within or near the transmitting equipment but arising as well at points in the transmission path wholly unassociated with either the receiving or transmitting equipment.

The evaluation of the magnitude of the contribution of each of these two potential sources to the observed spurious signals, obviously required carefully devised equipment and carefully chosen observational procedure.

For the former, special measuring equipment was devised and is pictured in Fig. 4. This comprised a signal strength indicator characterized by substantial freedom of internally generated cross modulation under exceptionally severe conditions.

For the latter and only after lengthy investigation had strongly indicated that at no point within the City of Seattle could satisfactory assurance of freedom from locally generated cross modulation be had, an extended series of measurements were made on Elliot Bay along the route labelled 1 to 7, and later at locations I to IV on the map shown in Fig. 1. This procedure established the fact that spurious signals of the cross modulation type were originating in or near KOMO, KJR and KOL and made it possible to measure the signal strength of the two most frequently observed spurious signals originating at or within the transmitting equipment of KOMO and KJR. Similarly, measurements were made of the signal strength on the assigned frequencies of KOMO and KJR, the ratio of the "spurious" to the "real" signals so measured later providing the basis for differentiating between those observed spurious signals which originated in the neighborhood of the transmitters and those spurious signals which originated elsewhere.

Cross Modulation in or near the Transmitters

The results of this portion of the work can best be reported by quoting from Bulletin No. 28 as follows:

> (1) "There is cross modulation between the three closely positioned transmitters KOL, KOMO and KJR originating in their immediate vicinity."
>
> (2) "On Elliott Bay, the ratio of the cross modulation signal originating in or near the transmitting equipment of KOMO and KJR to the signals on the assigned frequencies of these transmitters is approximately 1×10^{-4}."

Cross Modulation in the Transmission Path

Because of the lack of provision for a city-wide survey, of spurious signals a "sampling" procedure was adopted in that observations were made at five conventional receiver installations at widely separated points in the city labelled "A" to "E" in Fig. 1, which, in the opinion of the observers, were characterized by cross modulation interference ranging from "severe" to "negligible."

The immediate results of this portion of the work can best be reported by quoting from Bulletin No. 28 as follows:

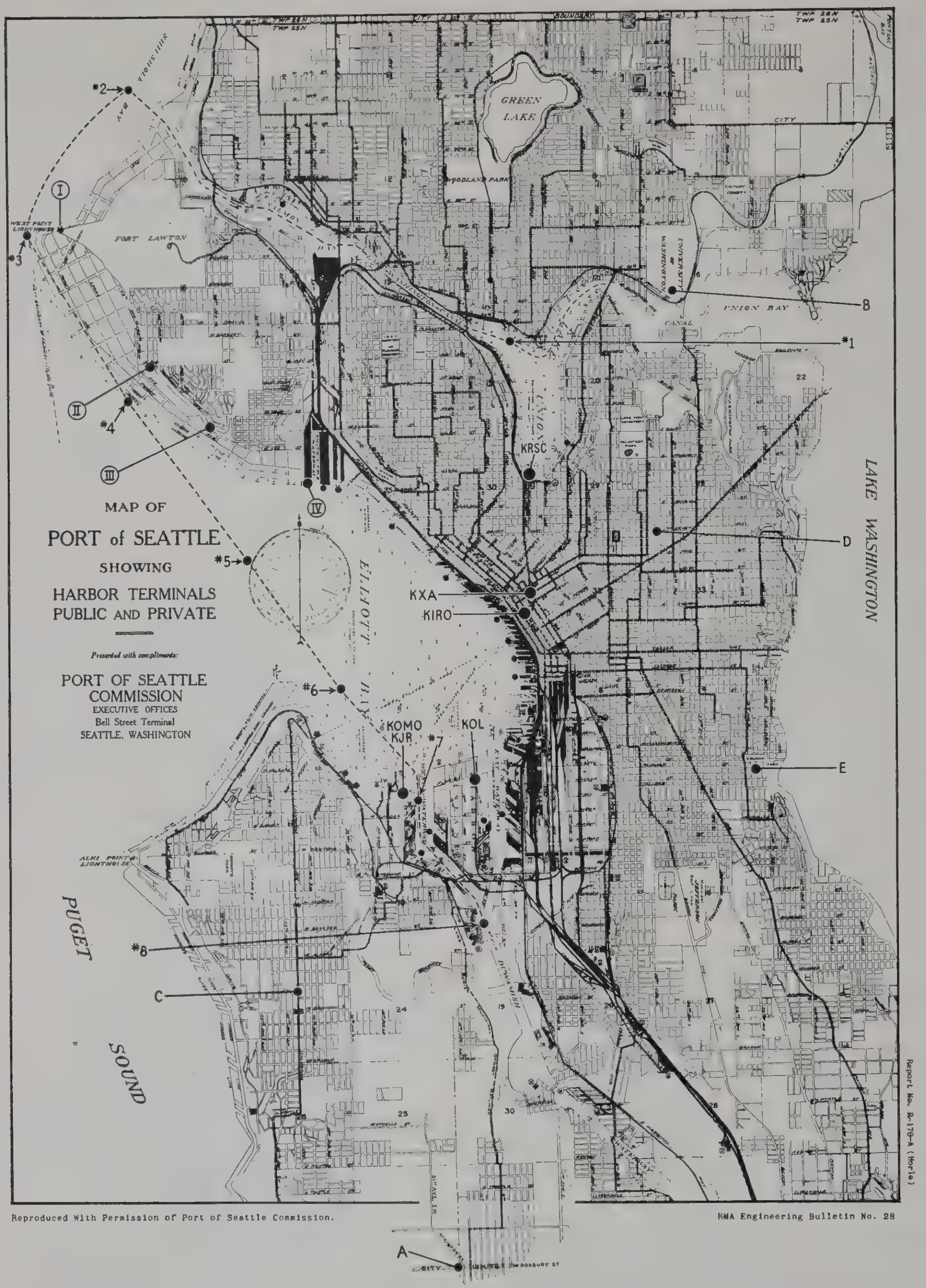
> "As observed in the City of Seattle, proper, the level of cross modulation as generated external both to the receiver and to the transmitters is 10-db or more above that originating in the immediate vicinity of the KOMO-KJR transmitters except in those locations where cross modulation interference, on the whole, is considered negligible."

The Rationale of External Cross Modulation

In addition to the development of these important and highly practical conclusions, attempt was made in Bulletin No. 28 and is here extended to develop from the host of data gathered in the Seattle investigation, a better understanding of the rationale and the quantitative relations involved in the generation of spurious signals by cross modulation external both to the transmitting and receiving equipment. In brief, this comprises the correlation of the measured cross modulation signals—as identified and differentiated from other and possibly spurious signals by the frequencies at which they appear—with the causative influence as computed on the basis of an assumed non-linear conductance as an element in the transmission path and from the value of the signal field strengths as measured at the several observation points within the city.

As a first step in this process of rationalization of external cross modulation an expression for the non-linearity to which the cross modulation might be attributed is set up. This, as is usual, takes the form of a power series in the applied voltage as the expression for the resulting current. In the practical case, the voltage here involved may be the space voltages of the radio waves: the voltage drop across the non-linearity or, indeed, practical conditions may require the interchange of the voltage and the current in the power series.

Again, in the practically important case, the causative voltage or current will take the form of a number of simultaneously applied sinusoidal voltages or currents of different frequencies which on substitution in the proper series express the resulting current or voltage. And because the effect of the non-linearity is to be examined with reference to frequency selective circuits, the several terms of the power series require reduction to terms



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RMA Engineering Bulletin No. 28

Fig. 1

involving only the first power of the resulting sum and difference frequencies.

For the purposes of this part of analysis the first five terms of the power series have been so treated, and because the determination of the value of all possible cross modulation frequencies requires that analysis be made of the presence of as many simultaneously applied sinusoidal voltages as the order of the term, the analysis of the first five terms of the power series has been carried through with five applied frequencies.

A preliminary comparison of the results of this analysis with the Seattle data shows immediately that the only terms of importance are those which result from the expansion and reduction of the quadratic and cubic terms of the power zones. These are:

From the quadratic term:

(1) $\frac{1}{2}Be_1^2 \cos 2\omega$, and

(2) $Be_1e_2 \cos (\omega_1 + \omega_2)$

And from the cubic term:

(3) $3/4Ce_1^2e_2 \cos (2\omega_1 + \omega_2)$ and

(4) $3/2Ce_1e_2e_3 \cos (\omega_1 + \omega_2 + \omega_3)$

In which the signal voltages, e_1, e_2, e_3, are those of frequencies ω_1, ω_2, ω_3, and B and C are the coefficients of the quadratic and cubic terms of the basic power series.

The general form of these several expressions immediately suggests the direction that further analysis might take. Thus each of these terms comprises three component factors. These are, in the reverse order of their appearance above,

First, the trigonometric factor involving the combinations of the basic frequencies: For obvious reasons this is here referred to as the "frequency factor." Its immediate usefulness lies, of course, in the fact that it provides the basis upon which it has been possible to cull out of the host of data gathered at Seattle that of interest to the investigation of cross modulation here discussed and to neglect the observations either erroneously reported or arising from other causes. In addition it suggests an interesting hypothesis which is later discussed.

Second, the voltage factor: In the general case of cross modulation generation, the voltage term, comprising the product of the appropriate powers of the voltages and the numeric, might well be termed the amplitude factor. However, in the specific case of the cross modulation generated in the transmission path of the radio system, it is believed that this term can most usefully, albeit loosely, be referred to as the field product factor, or, more briefly, the "field product" by way of emphasizing the fact that the influence of the field strength on the amplitude of the cross modulation is expressed, not by any one of the field strengths involved, **but by the product of the appropriate powers of the several field strengths** and the appropriate numeric. This too, is later discussed in greater detail.

Third, the undetermined coefficient (B and C): To give physical significance to this factor, reference must be had to the specific case under consideration. Thus, in the case of cross modulation originating in the transmission path, the evaluation of the coefficient is, in effect, the evaluation of the many associated factors that connect the value of the field product in any particular case with, for instance, the cross modulation input to the receiver. Thus implicit in the coefficient are such factors as configuration and orientation of the element in which is included the non-linearity giving rise to the cross modulation, especially as these purely mechanical characteristics determine the voltage induced in the element by the fields there present. In addition, there is implicit also the electrical characteristic of the element such as the velocity and attenuation of wave propagation along its length or such other characteristics as will determine the current at the non-linearity on the application of a space voltage of any frequency. And, of course, there is implicit also, the coupling between the element and the antenna of the radio receiver, expressible, perhaps as a field pattern where the element is remote from the receiving antenna, or, more simply, as a reactive and/or resistive coupling where the element and the receiving system are closely associated.

And since these factors, as implied in the coefficients B and C, express the susceptibility of any particular situation to cross modulation interference, requiring only the presence of radio fields and receiving stations in order that its presence may be felt, the term "susceptibility" factor has been suggested for the coefficient and is so referred to in this discussion.

With the distinctive characteristics of the several divisions of the expressions for the cross modulation in mind, several avenues of investigation immediately suggest themselves. Thus:

(a) Frequency Factor

Aside from its usefulness in identifying those spurious signals which arise from cross modulation, the frequency factor suggests the possible usefulness of the development of generalizations with respect to the pattern of cross modulation frequencies resulting from any pattern of assigned frequencies for the investigation of the influence of the latter on the seriousness of the resultant cross modulation interference.

Such a procedure leads directly to the suggestion that the discontinuity of the pattern of the frequencies assigned to the Seattle area—as contrasted with a continuous and uniform pattern such as is typified by 50-kc separation between all assignments in any one area, with the consequent masking of cross modulation signals by strong signals on assigned frequencies—may in part be responsible for the reports of the severity of the cross modulation interference in that area.

In suggesting this hypothesis, there is no neglect of the possibility that where coincidence is made relatively complete, there is danger of the cross modulation taking the form of "background" interference on the assigned frequencies. The quantitative data as gathered at Seattle, however, suggests that this may be the lesser of two alternative evils.

(b) The Field Product

Since the magnitude of the spurious signals resulting from cross modulation are indicated by the analysis to be proportional to the values of the field products there is suggested the possible value of an attempted correlation between the values of the field products for each of the possible cross modulation signals which might result from the simultaneous operation of the six Seattle transmitters and the frequencies at which spurious signals were actually observed.

To this end there were made at Locations "A" to "E" of Fig. 1 careful observations of the spurious signals there received and measurement of the field strength of the signals of the six more active Seattle stations.

While for a complete study of the phenomena here discussed a city-wide survey of both of these would probably be required, the limitations imposed on the work were such as to require resort to "sampling" in the process of which there were chosen five typical, conventional, broadcast receiver installations characterized by spurious signal interference ranging from what was considered "negligible" at Location "A" to "severe" at Location "E". At these locations the normally present broadcast receiver was replaced by the measuring set, and the frequencies of the spurious signals carefully measured and such additional data was gathered as later allowed of the evaluation of the signal input to the measuring set at the frequencies of the spurious signals as well as at the assigned frequencies of the local stations.

At these five locations the field strengths of the signals of the six local stations also were measured: not, however, without some difficulty as the result of the fact that at those locations which were characterized by the higher levels of spurious signals such serious field distortion was found as might not unexpectedly accompany the presence of high values of induced signal currents in nearby extensive conductors. At these locations, therefore, the measurements were made at such short distances from the receiver installation as served to avoid the field distortion.

From the data so gathered and using the quadratic and cubic terms given above there have been computed and, in part, plotted in Fig. 2 the field products corresponding to all of the cross modulation frequencies which might result from the operation of

KIRO	at	710 kc
KXA	"	760 kc
KOMO	"	920 kc
KJR	"	970 kc
KRSC	"	1120 kc
KOL	"	1270 kc

In Fig. 2 only those values of the field products corresponding to frequencies falling within the frequency range of the measuring set and only those in excess of 0.0002 $(v/m)^3$ are shown. And since at Locations "A" and "B" such low levels of spurious signals were observed as were largely attributable to radiation of spurious signals from the transmitter locations, while at Location "D" the noise level was such as to cast grave doubt on the significance of the observations at this location, only the values of the field products at Locations "C" and "E" are shown.

The values of the field products corresponding to the frequencies at which spurious signals were observed are indicated by the circular markers while those values of the field products corresponding to the frequencies at which **no** spurious signals were observed are marked by solid dots.

A casual inspection of this graph calls attention at once to the fact that there appears to be a relatively sharp line of demarcation—at a value of the field product of about 0.001 $(v/m)^3$—above which substantially all computed cross modulation signals were observed, while the converse obtains for values of the field products that are less than this value.

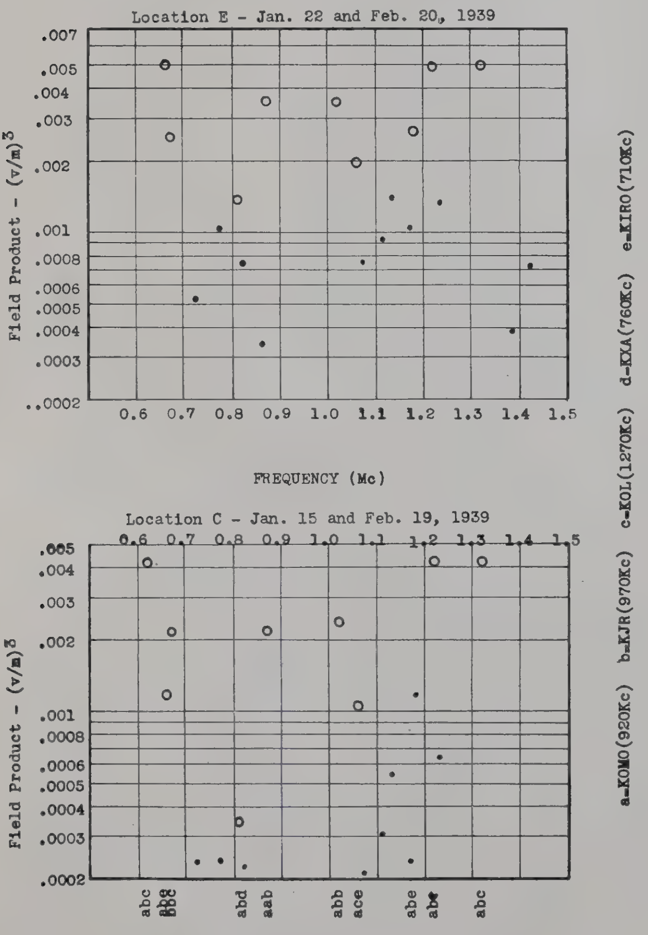

Fig. 2

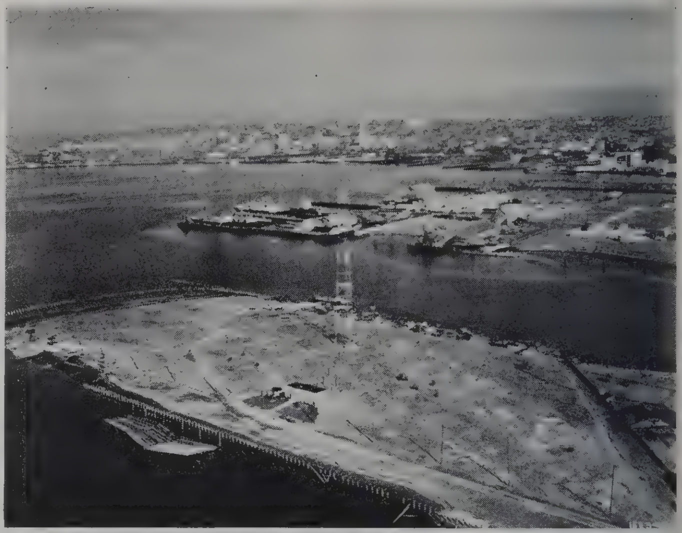

Fig. 3

In view of the basically non-linear nature of the phenomena here involved this suggestion of a threshold value is not wholly unexpected.

Of more importance, however, is it to note the minor difference in the threshold values at the two so diverse locations as are here involved. And while the data available for this analysis is far too meagre to provide the basis for any generalizations as to the permissible value of the field product which must **not** be exceeded if serious cross modulation interference is to be avoided, this correlation not only gives persuasive support as to the soundness of this approach to the determination of the quantitative relations here involved, but it establishes the fact that to the extent that the "sampling" on which the observation points were chosen is sound, a value of the field product of approximately .001 $(v/m)^3$ marks the difference between "severe" and negligible cross modulation interference.

For such interest as there may be in relating each of the observed spurious signals to the normal signals of the Seattle stations there is indicated in the lower margin of Fig. 2 the combination of stations the assigned frequencies of which correspond to the frequency of the observed spurious signals and from the signal field strengths of which the corresponding field products were computed.

From this it may be concluded that while KOMO and KJR are each related to nine of the ten observed spurious signals, KOL is similarly related to five of the spurious signals while KXA and KIRO are similarly but less numerously related.

This points to the likelihood of cross modulation interference when the transmitters are located as in the case of the Seattle stations. Thus, as will be noted from Fig. 1 and from the aerial view of Fig. 3, the three most powerful transmitters—KOMO, KJR and KOL—are located in the same small area on the south shore of Elliot Bay immediately adjacent to the West Seattle area and only about two miles south-west of the center of the city.

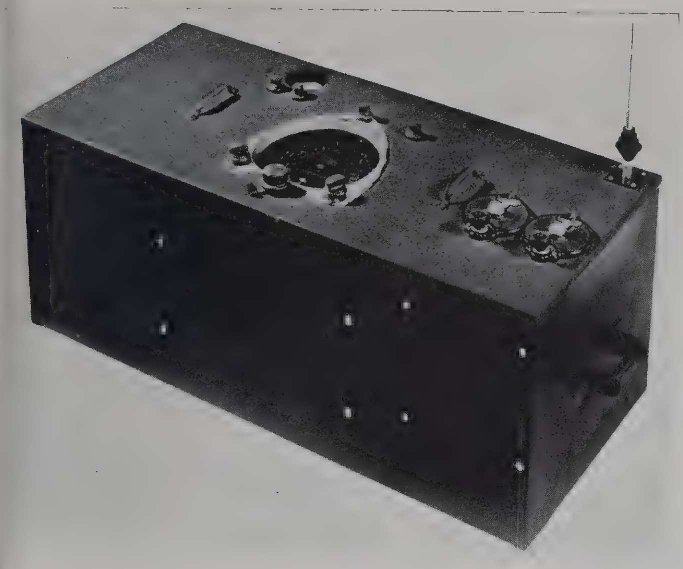

Fig. 4

It will be similarly noted that the two other of the area's six transmitters—KXA and KIRO—are located close to the very center of the downtown section of the city and only about one mile from the sixth of Seattle's transmitters.

The result of this particular arrangement of transmitter locations, is to create relatively large areas in which are simultaneously present high values of the field strengths of several stations with consequently high values of the resultant field product. These areas are, largely coincident with areas of relatively high population density and hence probably coincident with areas of relatively high values of the susceptibility factor—as is later referred to.

Under these conditions the prevalence of spurious signals resulting from cross modulation appears quite inevitable.

It is perhaps, to the point, to state again that the effects here discussed concern themselves **not with direct interaction between the transmitters themselves,** but only with the interaction between their signals and more especially with the interaction of signals in areas in which the field products exceed a value of .001. $(v/m)^3$. These effects are in fact, quite independent of such interaction between transmitters as may exist and appears to be related to direct transmitter interaction simply because the juxtaposition of transmitters—or, in the extreme case, the use of a common antenna—which may give rise to direct interaction between transmitters, inevitably gives rise to coincidence of field patterns and hence to the largest possible areas of high field products and potential cross modulation.

(c) The Susceptibility Factor

The preceding sections of this report will have been found to establish a correlation between the field product and the incidence of cross modulation. It does not, however, provide any basis whatsoever for the prediction of the magnitude of the cross modulation signals to be expected from any value of the field product under any set of local conditions. For this there is required an evaluation of the susceptibility factor.

As defined for the purposes of this specific report, the susceptibility factor is the ratio of the cross modulation voltage input at the radio receiver to the field product in the vicinity of the radio receiver. It has been computed from the values of the field products and the "Equivalent Spurious Input" as determined by calibration of the measuring equipment. The values so arrived at are shown in Fig. 5.

For the reasons enumerated above only the values of the susceptibility factor at locations "C" and "E" and within something less than the entire broadcast band are given in this figure. On this graph is given also the computed values of the effective heights of the receiving antennas used at these two locations.

A casual inspection of this graph emphasizes the wide range over which the susceptibility factor varies at either of these locations. In view, however, of the fact that there may be here involved resonances in structures of such relatively high "Q" as that of open wire lines and the like, the fact that at location "E" the susceptibility factor assumes value over a range of six to one is not difficult to understand. It may, perhaps, be of doubtful validity to refer to a mean value of the susceptibility factor or even to attempt to represent its variation with so simple a contour as is shown in the graph. It is felt, however, that such a reduction of the data as will serve to fix in the mind of the reader the order of magnitude of the value of this factor will thus serve a highly useful purpose.

Aside from this, it is to be noted that since under the conditions here reported, the susceptibility factor falls within the range of .01 and .20 and, as indicated in the preceding section, spurious signals made themselves evident for substantially all values of field prod-

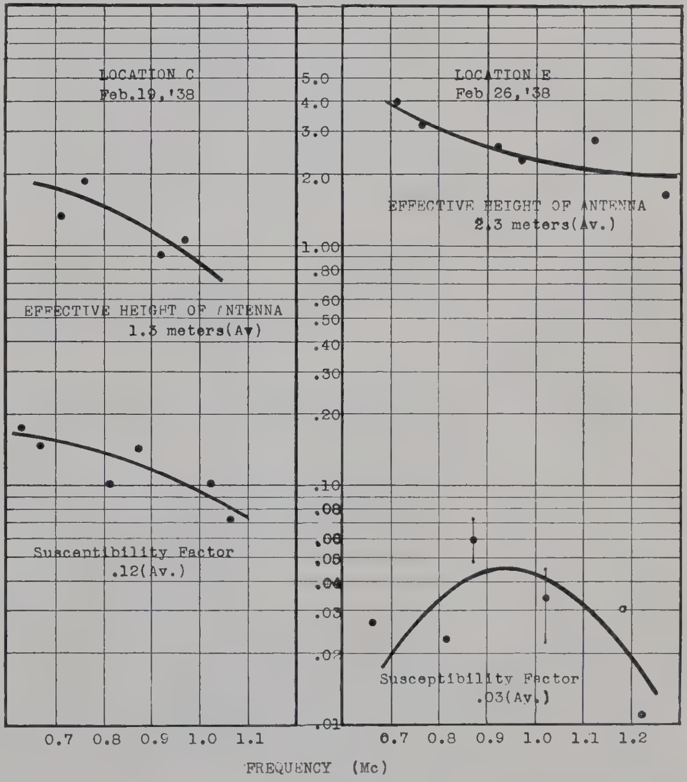

Fig. 5

ucts in excess of .001 $(v/m)^3$, it follows that the level of these spurious signals, will not be less than 10 μvolts and may easily approach a millivolt. Obviously, such levels as these will fall within the range of accommodation of the automatic volume control of modern broadcast receivers and thus give rise, not only to interference with desired signals of the frequency of the spurious signals, but give rise as well to the multiple reception of local and probably mutilated programs with the consequent confusion and complaint.

A complete analysis would here attempt the correlation of these values of the susceptibility factor with such physical and electrical conditions as may have characterized the locations at which these observations were made. Unfortunately, however, neither time nor opportunity allowed of the gathering of such data as would be required for such a correlation. Some meagre reports have, however, come to the writer which might here be mentioned.

Thus it is pointed out that Seattle is characterized by an extensive "over-head" electrical distribution system; both for high voltage, long distance, power transmission and for the local or secondary distribution throughout the city. It is further reported that the net-work of "over-head" is augmented by the duplicate distribution facilities of the two power companies operating in that area.

Experience in other areas where some cross modulation has been observed has suggested a correlation between the extent of the "over-head" electrical distribution system and the generation and distribution of spurious signals even where the electrical distribution system is well maintained and where the "over-head" is broken down into sections, many of which are short as compared with the wave length of the radio signals.

Information from other sources indicate that such building construction as characterizes areas of comparative uniformity of weather and of general clemency may be expected to markedly contribute to the generation of cross modulation.

Doubtlessly the power distribution systems of the area and the uniformly delightful weather reported from the Seattle area reflect themselves in the susceptibility factors here reported.

Conclusion

While it was not the purpose of the work here reported to develop the means for the reduction or elimination of the hazards to satisfactory radio reception resident in external cross modulation, the results of the work point unavoidably to the fact that if the spurious signals due to external cross modulation are to be avoided there are only two alternatives.

On the one hand either such choice of station locations or powers must be made as will limit such excessive values of the field products as are unavoidable to those areas as are of negligible population, or—

On the other hand, such modifications must be made of all extensive electrical systems and conductors within the areas of high field products as will reduce the susceptibility factor to an acceptably low value.

That both of these expedients are practicable is attested by the fact that in other areas suitable locations have been found for groups of transmitters all concentrating their service on the same relatively small area, while in other areas where the avoidance of the coincidence of areas of high field products and high population density was impracticable, the improvement of the details of the electrical distribution system and its continued, proper maintenance has served to reduce the difficulty to negligible proportions.

Basic to any intelligent movement to eliminate cross modulation interference must inevitably be an understanding of its rationale. It is hoped that this report will contribute to such an understanding.

The work reported in this and in Bulletin No. 28, comprises a cooperative project largely within the Engineering Division of R.M.A. The preliminary investigation at Seattle was made by Mr. G. E. Gustafson and under his direction the special measuring equipment was designed and built. The calibration of the equipment and the quantitative conversion of the field data was done under the direction of Mr. D. E. Foster. Preliminary and qualitative observations were made in Boston, Buffalo, DesMoines and Seattle, by or under the direction of C. T. Burke, H. C. Forbes, and N. Foster. The quantitative observations were made in Seattle by and under the direction of Prof. A. V. Eastman, while, for the most part, the writer concerned himself with the coordination of this wide range of activity and with the reporting of the results of the work.

LAWRENCE C. F. HORLE
Newark, N. J.
May 6, 1939.

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CHARACTERISTICS OF BROADCAST RECEIVERS 1938

(*Continued from Page 6*)

WEIGHTING

It will be noted that in the data here presented there is included no "weighting" in accordance with the quantities in which the models have been produced. A precise weighting of the data on that basis may, perhaps, be of considerable value. But in view of the fact that in the interest of the earlier publication of this summary report the detailed data was secured during the course of production rather than after its completion, no basis for precise weighting is yet available.

Data on the quantity in which each reported model was produced is being requested and may serve as the basis for the preparation of weighted summaries of the important characteristic data.

In the meantime, however, it should be noted that it is believed that the largely fortuitous weighting of the statistical distributions, which results from the fact that the sources of data to which the Data Bureau has access are such as to provide for the "sampling" rather than the complete survey of **all** of the models produced by **all** of the suppliers to the American market, gives these distributions greatly increased significance and makes them markedly more useful than such estimates as those to which effective resort has been had in the past.

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